PUBLIC ADVOCATES OFFICE
CALIFORNIA PUBLIC UTILITIES COMMISSION

Order Instituting Investigation into the November 2018 Submission of Southern California Edison Company's Risk Assessment and Mitigation Phase

I.18-11-006

Supporting Attachments to the Comments of the Public Advocates Office

San Francisco, California
June 2019

Supporting Attachments

Page	Footnote	Document
01	7	Excerpt from CalEnviroScreen 3.0 Report
04	15 and 43	SCE Response to Data Request CalAdvocates DR-01 Question 01
06	18	Near Miss Reporting: A Proactive Approach to Safety Management
10	20	Excerpt of CalOES Access and Functional Needs Webpage
13	22	LA Times Camp Fire Article (December 13, 2018)
22	36	PG&E's 2017 RAMP Report Excerpt (p. 1-19)
24	37	PG&E TY 2020 GRC CalAdvocates DR-31 Questions 01 and 04
32	49	SCE Response to Data Request CalAdvocates DR-02 Question 07
34	52	SCE Response to Data Request CalAdvocates DR-02 Question 08
36	63	5 Advantages of Face-to-Face Training
39	64	Key Benefits of Providing Health and Safety Training for Employees
43	88	CPUC-CalFire MOU
49	89	Cal Advocates Comments on PG&E's 2017 RAMP Report Excerpts (pp. 4, 5, 26, 40)
55	113	SCE Response to Data Request CalAdvocates DR-02 Question 09
58	124	Edison fined for its handling of nuke canisters
63	127	US Department of Energy Climate Change and the US Energy Sector Regional Vulnerabilities and Resilience Solutions Excerpts (pp. 3-1 to 3-20)

Excerpt from CalEnviroScreen 3.0 Report

AIR QUALITY: PM2.5

Particulate matter pollution, and fine particle (PM2.5) pollution in particular, has been shown to cause numerous adverse health effects, including heart and lung disease. PM2.5 contributes to substantial mortality across California. The health impacts of PM2.5 and other criteria air pollutants (ozone, nitrogen dioxide, carbon monoxide, sulfur dioxide, and lead) have been considered in the development of health-based standards. Of the six criteria air pollutants, particle pollution and ozone pose the most widespread and significant health threats. The California Air Resources Board maintains a wide network of air monitoring stations that provides information that may be used to better understand exposures to PM2.5 and other pollutants across the state.

Indicator

Annual mean concentration of PM2.5 (average of quarterly means, µg/m^3), over three years (2012 to 2014).

Data Source

Air Monitoring Network,
California Air Resources Board (CARB)

CARB, local air pollution control districts, tribes and federal land managers maintain a wide network of air monitoring stations in California. These stations record a variety of different measurements including concentrations of the six criteria air pollutants and meteorological data. The density of the stations is such that specific cities or localized areas around monitors may have high resolution. However, not all cities have stations.

The site information gathered from each air monitoring station audited by CARB includes maps, locations coordinates, photos, pollutant concentrations, and surveys.

http://www.arb.ca.gov/aqmis2/aqmis2.php
http://www.epa.gov/airquality/particlepollution/

Rationale

Particulate matter (PM) is a complex mixture of aerosolized solid and liquid particles including such substances as organic chemicals, dust, allergens and metals. These particles can come from many sources, including cars and trucks, industrial processes, wood burning, or other activities involving combustion. The composition of PM depends on the local and regional sources, time of year, location and weather. The behavior of particles and the potential for PM to cause adverse health effects is directly related to particle size. The smaller the particle size, the more deeply the particles can penetrate into the lungs. Some fine particles have also been shown to enter the bloodstream. Those most susceptible to the effects of PM exposure include children, the elderly, and persons suffering from cardiopulmonary disease, asthma, and chronic illness (US EPA, 2012a).

PM2.5 refers to particles that have a diameter of 2.5 micrometers or less. Particles in this size range can have adverse effects on the heart and lungs, including lung irritation, exacerbation of existing respiratory disease, and cardiovascular effects. The US EPA has set a new standard for ambient PM2.5 concentration of 12 μg/m^3, down from 15 μg/m^3. According to EPA's projections, by the year 2020 only seven counties nationwide will have PM2.5 concentrations that exceed this standard. All are in California (US EPA, 2012b).

In children, researchers associated high ambient levels of PM2.5 in Southern California with adverse effects on lung development (Gauderman *et al.,* 2004). Another study in California found an association between components of PM2.5 and increased hospitalizations for several childhood respiratory diseases (Ostro *et al.,* 2009). In adults, studies have demonstrated relationships between daily mortality and PM2.5 (Ostro *et al.* 2006), increased hospital admissions for respiratory and cardiovascular diseases (Dominici *et al*. 2006), premature death after long-term exposure, and decreased lung function and pulmonary inflammation due to short term exposures (Pope, 2009). A large study in six US communities, including Los Angeles, found an association between increased PM2.5 concentration and an increased risk of stroke (Adar *et al.*, 2013). A California study of long term PM2.5 exposure in women found significant associations with biomarkers of inflammation that can indicate increased risk of cardiovascular disease (Ostro *et al.,* 2014). Exposure to PM during pregnancy has also been associated with low birth weight and premature birth (Bell *et al.* 2007; Morello-Frosch *et al.,* 2010).

An additional source of PM2.5 in California is wildfires. Fires are not uncommon during dry seasons, particularly in Southern California and the Central Valley. Smoke particles fall almost entirely within the size range of PM2.5. Although the long term risks from exposure to smoke during a wildfire are relatively low, sensitive populations are more likely to experience severe symptoms, both acute and chronic (Lipsett *et al.* 2008). During the wildfires that spread throughout the state in June 2008, PM2.5 concentrations at a site in the northeast San Joaquin Valley were far above air quality standards and approximately ten times more toxic than normal ambient PM (Wegesser *et al.* 2009).

Method

- PM2.5 annual mean monitoring data was extracted from all monitoring sites in California from CARB's air monitoring network database for the years 2012-2014 with the exception of the monitors at San Ysidro and Otay Mesa where only 2015

SCE Response to Data Request CalAdvocates DR-01 Question 1

Southern California Edison
I.18-11-006 – SCE 2018 RAMP

DATA REQUEST SET C a l P A - S C E - 0 1

To: CalPA
Prepared by: Gary Cheng
Job Title: Senior Advisor
Received Date: 12/20/2018

Response Date: 1/8/2019

Question 01: Question 1
For each of the nine risk areas identified in SCE's RAMP filing,
a. Please provide the input file for SCE's risk model with the relevant @Risk formulae and syntax such that the Public Advocates Office would be able to independently fit distributions using SCE's input for the @Risk plug-in.
b. Please specify the random seed used in fitting the distributions.

Response to Question 01:

Please refer to the response to SED-SCE-Verbal-002, Question 1, for the risks models used in SCE's 2018 RAMP report.

Response to Question 01 (b):

The random seed is embedded into the Excel formulas, so there is no need to set random seeds when running the model.

As an example, one of the Excel formula is:

```
=RiskPoisson(G15,RiskSeed(1,N18))
```

"RiskSeed" is an @Risk function that will set the seed.

Near Miss Reporting: A Proactive Approach to Safety Management

Welcome to the EHS Insight Blog

Near Miss Reporting: A Proactive Approach to Safety Management

Posted by EHS Insight Resources on November 17, 2014 at 3:30 PM
Find me on:

Near miss reporting is an important indication of safety management system maturity. "Near miss" or "near hit" refers to any unplanned event that has the potential to incur loss, injury, or damage, but didn't. An organization that not only tracks near misses, but examines how and why they occur can prevent future incidents through the use of corrective actions.[1] With enough commitment to such a system, an organization can foster a culture that promotes, pursues, and praises proactive efforts such as near miss tracking.

A mature safety management system, and the safety personnel who operate within its framework, leverages a healthy mixture of both leading and lagging indicators. The opportunity to learn lessons from an event that had potentially disastrous consequences is valuable. Such occurrences within the company can be measured as a leading indicator, and could predict future outcomes when compared to lagging indicators from analysis gathered during incident investigations.

There can be obstacles to introducing a near miss reporting program. Near miss reporting is often seen as a top-down management initiative and does not appeal to the average employee, who has a "what's in it for me" mentality. Many companies struggle to make near miss reporting part of their culture because of a gap between management and the workforce that they are charged with protecting.

Because of the nature of a near miss, i.e. lack of evidence that a loss-producing incident could have occurred, employees tend to lack the confidence that their reports will be acted on, or even viewed positively, by their supervisors and upper management. Fear of punishment and retaliation cripple these efforts when employees have to consider if their report will make their supervisor look bad. In an article Mike Williamson, a Senior Safety Consultant from Caterpillar Inc., mentions a training session where workers told stories about supervisors giving the most undesirable jobs to "troublemakers who made waves by reporting problems."[2] This is a clear example of failure by management to establish a culture that promoted safety performance through reporting near misses, and rewarding those who participate.

There are also pressures that exist through workplace interaction that can affect a near miss reporting program taking root in an organization. Upon observing an unsafe condition, an employee must quickly decide whether the observed hazard is worth the immediate attention, and potential work interruption, that may ensue.[3] However, in a near miss situation, taking action can be the difference between a hazard being mitigated, and serious injury being sustained by a worker. It is up to the employer to establish a sense of confidence and security in near miss reporting, removing the fears associated with raising questions about workplace safety.

Recent Posts

- Why You Should Participate in National Safety Month this June
- How to Reduce Stress at Work
- Incident Investigation Blog Series – Part 2: Methodologies and Models

CalAdvocates-SA-07

To help organizations achieve safety success, we published an eBook which examines five practices that help strengthen safety cultures. Download it today and learn more about how you can implement each practice in your organization.

GET eBOOK

The following are several ways to improve the chances of a successful program taking hold in your organization:

1. **Perform an investigation** – Near misses should be taken seriously, especially those with a high potential severity. Performing an investigation to determine root causes, then applying appropriate controls, is a great way to develop lessons learned that can be distributed back to the organization. This shows that near miss reporting is important to management, that action is being taken, and that the safety of the workforce is being put first.
2. **Introduce near miss reporting during training** - A first impression will stay with an employee as they go through orientation and are introduced to a new management system. Share information about successful near miss reporting from the past, and train employees on how to speak up in their work environment. Have a member of management present to work through these scenarios with employees in order to build confidence that reporting an unsafe observation is the right thing to do.[4]
3. **Make the process easy** – Eliminate red tape by presenting a streamlined near miss report form. Increase the chances of gathering quality information by cutting down on the number of questions. Ensure that the reporting system is non-punitive and, if consistent with management policy, anonymous.

When these best practices are adhered to, the benefit to a safety focused organization is significant. Here is some feedback we've heard from our clients who use EHS Insight as part of their near miss reporting strategy.

1. **Information** - Near miss data provides the chance for meaningful statistical analysis. Trending and performance measurement are made easier with near missing as a telling leading indicator. Understanding near misses will aid in predicting where serious injuries and losses are likely to occur, which is useful information for management.
2. **Culture** – Create an open accountability system that is dependent on support from employees all the way up to management. Avoid setting quotas; instead incentivize reporting with meaningful rewards. Praise good efforts; provide updates on progress and make the count of near miss forms submitted available.
3. **Safety** – Organizations that implement near miss programs almost always credit them with improving safety. Near miss programs go a long way in improving a range of safety goals, from OSHA recordable numbers to lower total incident rates.

The success of a near miss reporting program is dependent on an entire team's commitment to safety. Once implemented, a near miss reporting provides a great leading indicator of safety performance, a core tenant of a hazard identification system and a means of engaging and empowering employees throughout different levels of an organization.[5]

[1] Morrison, Kyle W. "Reporting near Misses." Why Reporting near Misses Is Important. Safety & Health Magazine, 24 Aug. 2014. Web. 13 Nov. 2014. <http://www.safetyandhealthmagazine.com/articles/10994-reporting-near-misses>.

[2] Williamsen, Mike. "Near-Miss Reporting: A Missing Link in Safety Culture," ASSE, Professional Safety, May 2013.

[3] Ibid.

[4] Ibid.

[5] "Near Miss Reporting Systems." National Safety Council, 2013. Web. 13 Nov. 2014. <http://www.nsc.org/WorkplaceTrainingDocuments/Near-Miss-Reporting-Systems.pdf>

Topics: EHS Software, Performance Improvement, Process Safety, Workplace Health and Safety

First Name*

- SDS Software Management System: SDS Program Library Solution
- Safety Meeting Topics: The Best Ideas for Work Huddles

Posts by Tag

- Workplace Health and Safety (191)
- EHS Management (123)
- EHS Software (89)
- Safety Management (79)
- Compliance (67)

See all

CalAdvocates-SA-08

Last Name

Email*

Website

Comment*

protected by reCAPTCHA
Privacy - Terms

Submit Comment

StarTex

Excerpt of CalOES Access and Functional Needs Webpage

Access & Functional Needs

1

Share This Page

About Us

No two disasters are ever the same; yet, virtually all incidents disproportionately affect individuals with access and functional needs (AFN) (i.e. people with disabilities, seniors, children, limited English proficiency, and transportation disadvantaged). Understanding this harsh reality, in 2008 California established the Office of Access and Functional Needs (OAFN) within the Governor's Office of Emergency Services.

The purpose of OAFN is to identify the needs of individuals with disabilities and others with access and functional needs before, during and after disasters and to integrate them into the State's emergency management systems.

OAFN utilizes a whole community approach by offering training and guidance to emergency managers and planners, disability advocates and other service providers responsible for planning for, responding to and helping communities recover from disasters. In short, OAFN plans for the realities of disasters by integrating access and functional needs into everything Cal OES does including partnership development, outreach, training, guidance and providing technical assistance.

Luis “Vance” Taylor is the Chief of the Office of Access and Functional Needs.

Understanding Access and Functional Needs

Access and functional needs (AFN) refers to individuals who are or have:

- Physical, developmental or intellectual disabilities
- Chronic conditions or injuries
- Limited English proficiency
- Older adults
- Children
- Low income, homeless and/or transportation disadvantaged (i.e., dependent on public transit)
- Pregnant women

****Detailed guidance on integrating AFN can be found in the AFN library*

Cal OES Integrates Access and Functional Needs Within Updated Active Shooter Awareness Guidance

Following the active shooter attack on December 2, 2015 at the Inland Regional Center in San Bernardino, initial reports indicated it was an assault on the disabled. Though we later learned this was not the case; the thought of an attack on individuals with disabilities raised serious

LA Times Camp Fire Article (December 13, 2018)

Many victims of California’s worst wildfire were elderly and died in or near their homes, new data show

By MARIA L. LA GANGA, LAURA NEWBERRY, PAIGE ST. JOHN and RONG-GONG LIN II
DEC 13, 2018 | 4:35 PM

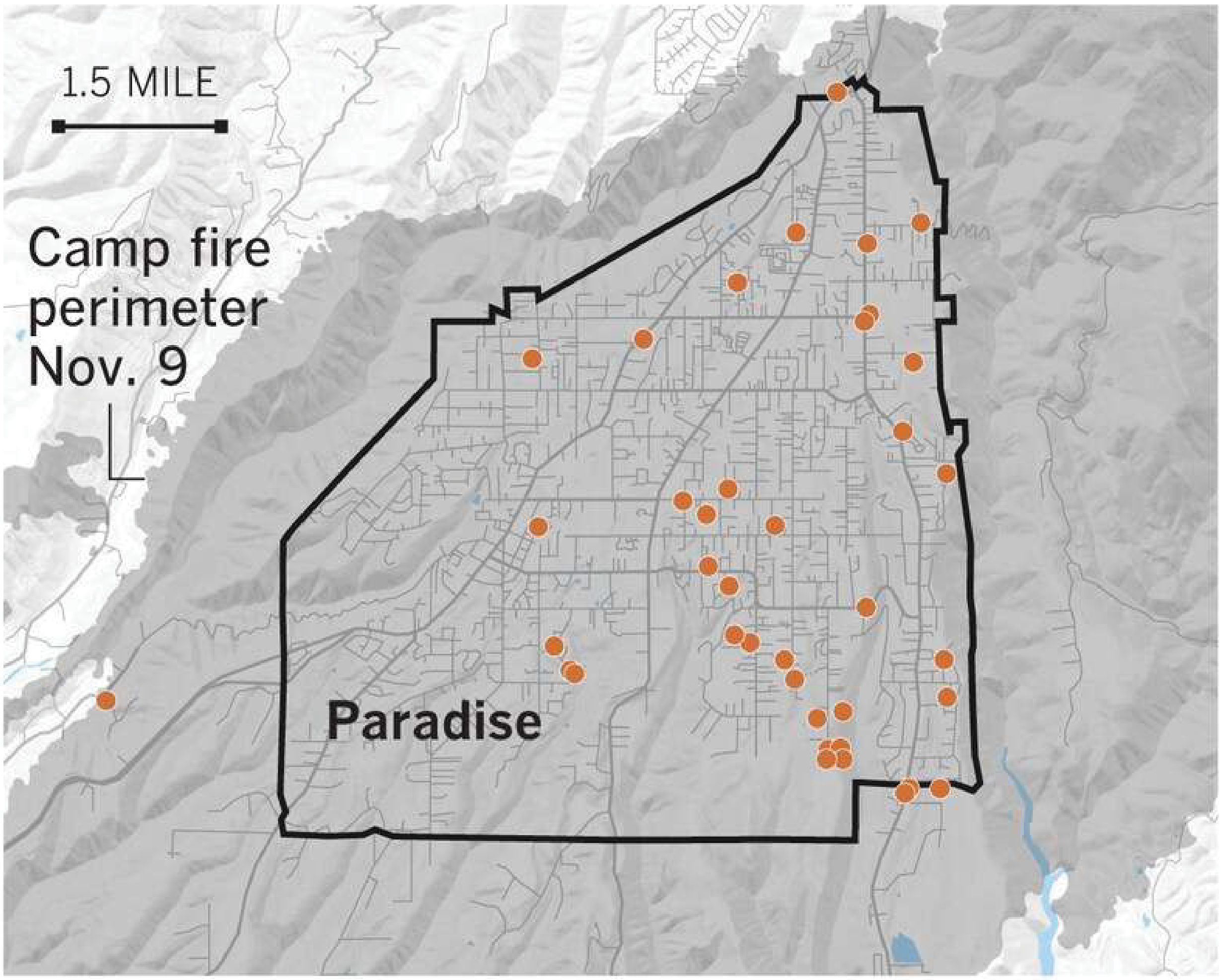
A search-and-rescue team carefully scans the area where there might be human remains after the Camp fire destroyed most of Paradise, Calif. (Marcus Yam / Los Angeles Times)

Rose Farrell is the oldest victim of the devastating Camp fire to be identified so far. She was 99, and she died inside her home on Herman Road in Paradise.
Evva Holt, 85, died inside a pickup truck after she was evacuated from Feather Canyon Gracious Retirement Living. She made it only a mile.
Richard Brown, who was 74 when the blaze overcame him, died underneath a vehicle. He'd managed to travel less than a quarter-mile from his home in the tiny Sierra Nevada town of Concow.

The Camp fire killed 86 people. Of those, 53 women and men have been identified by officials so far. On Thursday, the Butte County Sheriff's Office released the locations of where their remains were found. Although the victims' official causes of death have not been released, search teams have described finding bones and bone fragments in the ashes.

Where Camp fire victims died in Paradise

At least 38 people died in Paradise during the Camp fire, according to authorities.



Source: Butte County Sheriff's Office @latimesgraphics

(Ellis Simani / Los Angeles Times)

The Times received the locations after filing two requests and an appeal under the California Public Records Act. The county initially refused to release the records, even after family members had been notified about the deaths and the victims' names had been publicly released.

The information paints a terrible picture of age, infirmity and, in some instances, stubbornness. The victims who have been identified range in age from 39 to 99; however, 60% were in their 70s, 80s or 90s.
Sixty percent also were found inside homes, buildings that under normal circumstances offer comfort and refuge. Twenty percent were found just outside of residences. Eight individuals' remains were found in cars ostensibly headed for safety.'

Larry Smith, an 80-year-old from Paradise, died at UC Davis Medical Center. He was badly burned while attempting to put out the flames that engulfed his car.

It is impossible to know what caused so many of the fire's victims to remain home while thousands of their neighbors fled. Many people in the mountain community never received an official evacuation warning. Some of those who heard warnings of looming danger might not have been mobile enough to heed them.

Others chose to stay put as the deadliest wildfire in California history bore down.

The remains of Victoria Taft, 67, were found inside the home on Copeland Road in Paradise where she lived with her 25-year-old daughter, Christina. The pair didn't receive an official evacuation order the morning of Nov. 8, but a neighbor knocked on their door to tell them about the blaze.

At 10 a.m., Christina made a decision: They needed to leave. But her mom wanted to stay. She had been on the phone with a friend who also chose not to flee. The mother and daughter fought. After much pleading, Christina left. She took their only car.

As she headed toward Chico — a harrowing trip that took nearly two hours — Christina realized she might never see her mother again.

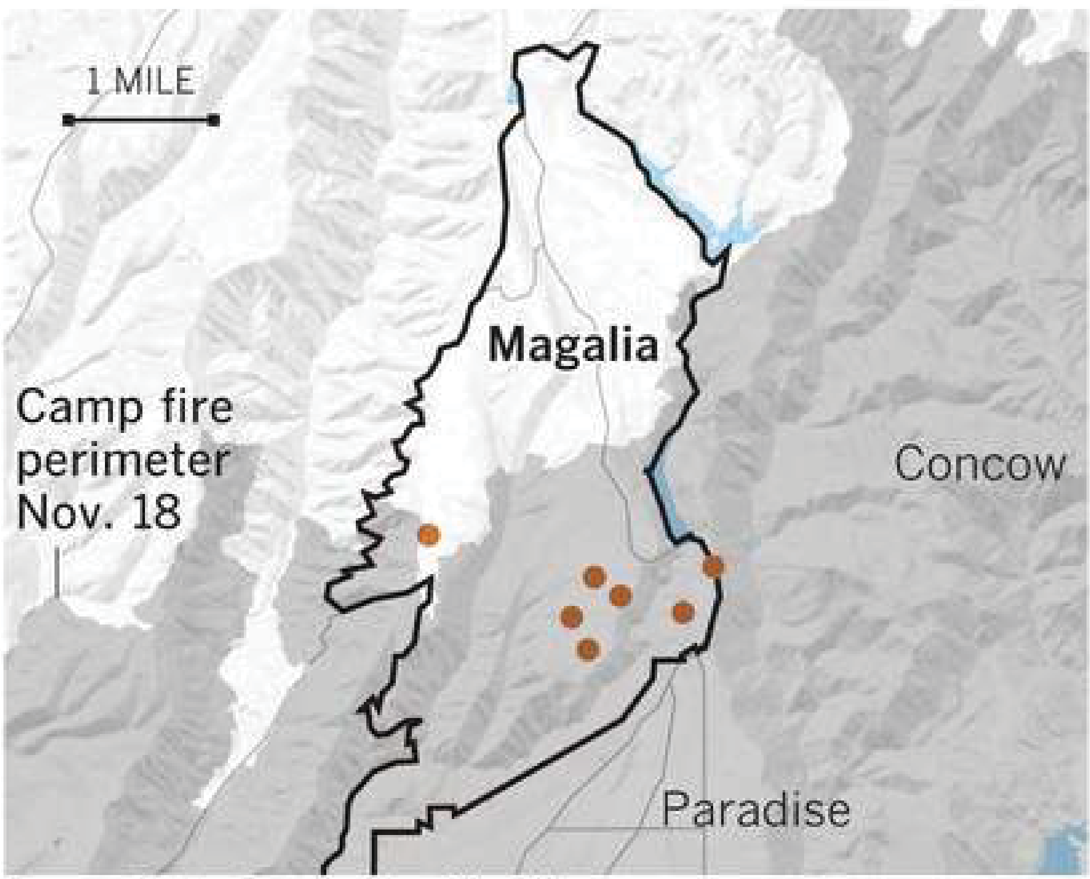
She was right.

“I was defeated,” Christina said. “But I could’ve waited longer. Maybe I could’ve gotten someone else to convince her.”

The remains of James Garner, a 63-year-old Navy veteran, were found inside his mobile home on Woodbury Drive in Magalia. His sister, Linda Baucom, said a relative who lived two blocks down from Garner had knocked on his door and urged him to leave the morning of the fire.

Where Camp fire victims died in Magalia

At least 7 people died in Magalia during the Camp fire, according to authorities.



Source: Butte County Sheriff's Office @latimesgraphics

(Ellis Simani / Los Angeles Times)
Garner used a cane, had back problems and couldn't move very quickly, Baucom said.
"He didn't believe that the fire was coming up that way," Baucom said. "He had never seen anything like that. I think he was just too stubborn to leave his home."

Evva Holt's remains were found near Pearson and Stearns roads, about half a mile from her unit at the Feather Canyon retirement home. Holt's daughter, Linda Dighton, said someone who worked at the facility had helped Holt into a pickup truck and tried to drive her out of danger.

The truck was on Pearson Road heading toward Skyway — the route to safety — when traffic came to a standstill near Stearns Road, authorities told Dighton.

Then there was an explosion. The truck caught fire. The Feather Canyon employee was able to pull one passenger out, Dighton said, but her mother was already too injured from the flames to be removed from the vehicle.
Holt, a retired dietitian, had lived at Feather Canyon for four years. She loved to play pinochle and go shopping. She was in good health for her age, said Dighton, who also lost her home in the Camp fire.

The remains of Julian Binstock, 88, were found inside the Feather Canyon home.

One of the grimmest discoveries was the carnage along Edgewood Lane, where at least six people died. The remains of two women and two men, who appeared to be neighbors, were found in one or more vehicles at the intersection of Edgewood and Marston Way.

They were fleeing to safety.

But they ended up halfway between their homes and a dead end.

(Ellis Simani / Los Angeles Times)

One survivor of the blaze, an older dog-owner in a rickety Jeep, recorded a video along Edgewood. It is 3 minutes and 32 seconds long, sepia-toned and posted on YouTube. It begins with what is left of a body curled on the ground and goes on to show burned-out cars with skeletal remains, flesh torched cleanly off skulls.

The shaky-voiced narrator describes some of the dead as friends and acquaintances. He marvels that he made it out alive.

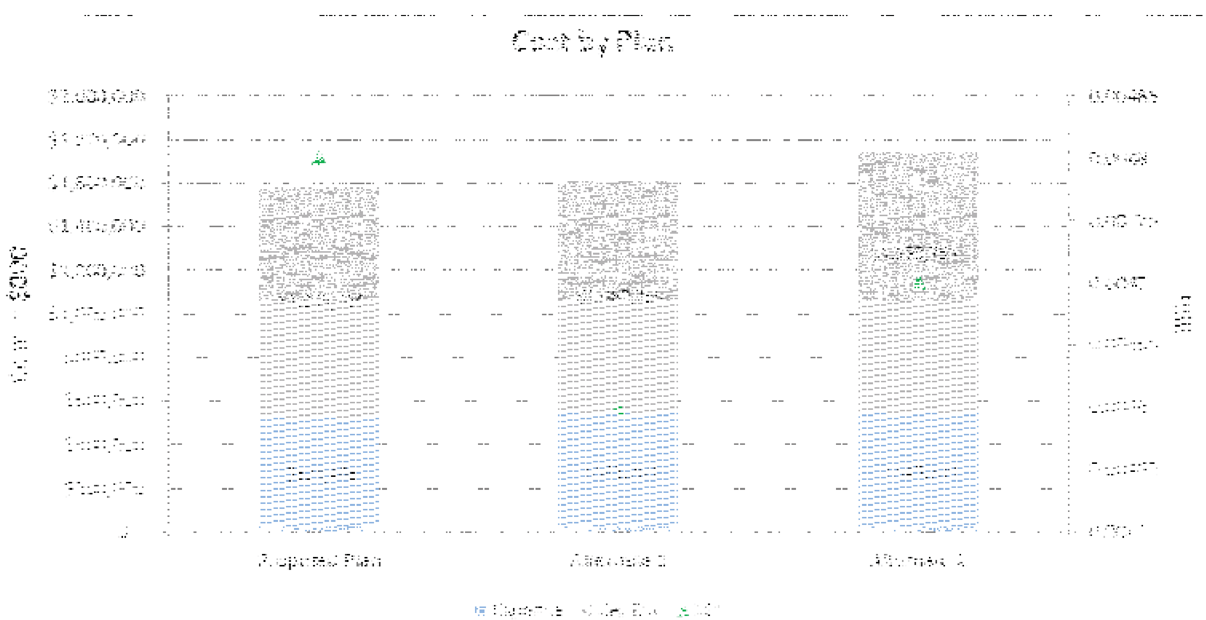
“These people got burned out in their cars like I almost did,” he says. “Dead, dead, dead.

“Everybody here is dead.”

Times staff writer Ben Welsh contributed to this report.

PG&E's 2017 RAMP Report Excerpt (p. 1-19)

Figure 1-3: Alternatives by Cost and RSE Score



A. Alternative Plan 1

The mitigation programs described in detail in Section IV above are also the mitigations for this alternative proposal. In this alternative, the pace of hydrostatic tests is increased in 2022 and more miles of shallow and exposed pipeline are replaced in the 2020-2022 period. This alternative was not selected based on SME evaluation of current controls and mitigations required to lower risk with considerations for cost. The scope of the mitigations considered for this alternative and the justification for why this option is not selected is listed below:

M1C – ILI: This alternative maintains the same scope and pace as the proposed case and includes first time inspection of 347 miles in 2020, 417 miles in 2021, and 227 miles in 2022. The scope and pace stay the same because it is meeting CPUC D.16-06-056 to meet a 12-year pace.

M2D – Hydrostatic Testing: The alternative entails hydrostatically testing more miles in 2020-2022 than the proposed case to complete all the NTSB recommended miles by 2021. For 2022, given that the NTSB recommended miles are completed by 2021, this alternative proposes completing other non-HCA miles. It includes hydrostatically testing 98.3 miles in 2022 compared to 33.7 miles in the proposed case. While this approach more aggressively completes the NTSB pipe objectives, the costs would be significantly higher with minimal consequential risk reductions given that the sections of pipe included in 2022 are not near people.

PG&E TY 2020 GRC
CalAdvocates DR-31
Questions 01 and 04

PACIFIC GAS AND ELECTRIC COMPANY
2020 General Rate Case Phase I
Application 18-12-009
Data Response

PG&E Data Request No.:	PubAdv_031-Q01		
PG&E File Name:	GRC-2020-PhI_DR_PubAdv_031-Q01		
Request Date:	January 23, 2019	Requester DR No.:	031
Date Sent:	February 27, 2019	Requesting Party:	Public Advocates Office
PG&E Witness:	Various	Requester:	Pui-Wa Li

SUBJECT: EXHIBIT (PG&E-2) – EXCEL FILES SUPPORTING EXHIBIT (PG&E-2)

QUESTION 01

Is PG&E proposing any new risk programs in this GRC proceeding that were not previously identified in 2017 RAMP filing? If yes:

a) Please list out those newly proposed risk programs,

b) Explain why these programs were not previously introduced, and

c) Describe how these new programs will contribute to risk reductions.

ANSWER 01

Electric Distribution – Distribution Overhead Conductor Primary (David Gabbard)

Part a) Response	Part b) and c) Response
Enhanced Vegetation Management (EVM)	[b) The Overhang Clearing (M8) mitigation was folded into Enhanced Vegetation Management (EVM), driven by the analysis of the wildfire risk. This mitigation has been updated to correspond with changes made to that same mitigation in the Wildfire risk model. See Part b in the Wildfire Risk answer below. c) This mitigation will continue to reduce the frequency of the D2 – Vegetation risk driver." (See Exhibit (PG&E-4), Ch 2, Pg. 2-9, Line 8-9). See Exhibit (PG&E-4), Pages 2-5 to 2-11 for a discussion of the DOCP Risk Driver, Controls and Mitigations, and changes since the RAMP report.

Electric Distribution - Wildfire RAMP Risk (Sumeet Singh)

The response below refers to the GRC 2020 testimony served on December 13, 2018. The electric distribution testimony (PG&E-4) may be revised following the Commission's decision regarding PG&E's 2019 Wildfire Safety Plan, filed on February 6, 2019, as directed by the Commission.

Overall, mitigations in the GRC build on those mitigations identified in RAMP and generally have evolved based on the January 2018 CPUC fire map, requirements from the CPUC in D.17-12-024, analyzing CPUC-reportable ignitions and associated mitigation program effectiveness, and wildfire risk reduction measures benchmarking with domestic and international utilities.

a) Enhanced Vegetation Management (EVM)	b) In the 2017 RAMP Report, PG&E proposed two VM-related mitigations: Fuel Reduction and Powerline Corridor Management (M3) and Overhang Clearing (M4). Based on risk assessment work performed under the Community Wildfire Safety Program (CWSP), PG&E is now proposing an EVM mitigation program that is more comprehensive and will focus on Targeted Tree Species Work, Overhang Clearance, and Targeted Fuel Reduction to reduce vegetation contacts with energized distribution overhead conductors. c) Details describing the scope of this program are discussed in Exhibit (PG&E-4), Chapter 7 (MWC HN and MWC IG), and Exhibit (PG&E-4), Chapter 2A.
a) Vegetation Increased Line Clearances	b) This mitigation involves increasing vegetation-to-line clearances in Tier 2 and Tier 3 HFTD areas from 18 inches to 48 inches as required by the CPUC in D.17-12-024. This requirement was established after the 2017 RAMP Report was filed. c) Details describing the scope of this program are discussed in Exhibit (PG&E-4), Chapter 2A.
d) Wildfire System Hardening	e) In the 2017 RAMP Report, PG&E proposed: Targeted Conductor Replacement (WF). Based on risk assessment work performed under the CWSP, PG&E is now proposing a mitigation program of Wildfire System Hardening that is more comprehensive that may include: (1) replacing primary and secondary conductor with insulated or covered conductor; (2) replacing existing wood poles with more resilient poles including non-wood poles; (3) replacing of existing primary line equipment; (4) replacing overhead distribution line transformers; (5) upgrading distribution protection systems; and (6) conversion of overhead distribution lines to underground cable where feasible and prudent. f) Details describing the scope of this program are discussed in Exhibit (PG&E-4), Chapter 6 (MWC 2A), Chapter 9 (MWC

	08) and Exhibit (PG&E-4), Chapter 2A.
a) Resilience Zones	b) Resilience Zones are being implemented primarily as a complement to the Public Safety Power Shutoff (PSPS) Program that was developed as part of the CWSP in 2018. c) Details describing the scope of this program are discussed in Exhibit (PG&E-4), Chapter 9 (MWC 49) and Exhibit (PG&E-4), Chapter 2A.
a) Public Safety Power Shutoff (PSPS)	b) PSPS program was not part of the 2017 RAMP Report as the program had not yet been developed at the time. c) Details describing the scope of this program are discussed in Exhibit (PG&E-4), Chapter 3 (MWC AB) and Exhibit (PG&E-4), Chapter 2A.
a) Reclose Blocking	b) In the 2017 RAMP Report, PG&E proposed: Wildfire Reclosing Operation Program (SCADA Programming) (M1). Based on risk assessment work performed under the Community Wildfire Safety Program (CWSP), PG&E has continued to expand the use of this procedure beyond the then existing Fire Map and aligned this program to line reclosers and circuit breakers that protect lines in Tier 2 and Tier 3 HFTD areas based on the January 2018 CPUC fire map when fire conditions are elevated above a certain threshold. c) Details describing the scope of this program are discussed in Exhibit (PG&E-4), Chapter 5 (MWC BA) and Exhibit (PG&E-4), Chapter 2A.
a) Automation and Protection	b) In the 2017 RAMP Report, PG&E proposed: Wildfire Reclosing Operation Program (SCADA Capability Upgrades) (M2). Based on risk assessment work performed under the CWSP, PG&E has continued installing SCADA capabilities on reclosers and expanded additional protective devices, such as additional reclosers and new devices called, “Fusesavers.” c) Details describing the scope of this program are discussed in Exhibit (PG&E-4), Chapter 5 (MWC HG), Chapter 9 (MWC 49), Chapter 10 (MWC 09) and Exhibit (PG&E-4), Chapter 2A.
a) Wildfire and Infrastructure Protection Teams	b) Wildfire and Infrastructure Protection Teams was not part of the 2017 RAMP Report as the program had not yet been developed at the time. c) Details describing the scope of this program are discussed in Exhibit (PG&E-4), Chapter 3 (MWC AB) and Exhibit (PG&E-4), Chapter 2A.
a) Aviation Resources	b) Aviation Resources was not part of the 2017 RAMP Report as the program had not yet been developed at the time.

	c) Details describing the scope of this program are discussed in Exhibit (PG&E-7), Chapter 2 (MWCs BP, 21) and Exhibit (PG&E-4), Chapter 2A.
a) Wildfire Safety Operations Center	b) Wildfire Safety Operations Center was not part of the 2017 RAMP Report as the program had not yet been developed at the time. c) Details describing the scope of this program are discussed in Exhibit (PG&E-4), Chapter 3 (MWCs AB, 21) and Exhibit (PG&E-4), Chapter 2A.
a) Expanded Weather Station Deployment	b) Expanded Weather Station Deployment was not part of the 2017 RAMP Report as the program had not yet been developed at the time. c) Details describing the scope of this program are discussed in Exhibit (PG&E-4), Chapter 3 (MWCs AB, 21) and Exhibit (PG&E-4), Chapter 2A..
a) SOPP (System Outage Prediction Project) Model Automation	b) SOPP Model Automation was not part of the 2017 RAMP Report as the program had not yet been developed at the time. c) Details describing the scope of this program are discussed in Exhibit (PG&E-4), Chapter 3 (MWCs AB) and Exhibit (PG&E-4), Chapter 2A.
a) Advanced Fire Modeling	b) Advanced Fire Modeling was not part of the 2017 RAMP Report as the program had not yet been developed at the time. c) Details describing the scope of this program are discussed in Exhibit (PG&E-4), Chapter 3 (MWCs AB, 21) and Exhibit (PG&E-4), Chapter 2A.
a) Wildfire Cameras	b) Wildfire cameras were not part of the 2017 RAMP Report as the program had not yet been developed at the time. c) Details describing the scope of this program are discussed in Exhibit (PG&E-4), Chapter 3 (MWCs AB) and Exhibit (PG&E-4), Chapter 2A.
a) Satellite Fire Detection System	b) Satellite Fire Detection System was not part of the 2017 RAMP Report as the program had not yet been developed at the time. c) Details describing the scope of this program are discussed in Exhibit (PG&E-4), Chapter 3 (MWCs AB) and Exhibit (PG&E-4), Chapter 2A.
a) Enhanced Wire Down Detection	b) Enhanced Wire Down Detection was not part of the 2017 RAMP Report as the program had not yet been developed at the time. c) Details describing the scope of this program are discussed in Exhibit (PG&E-4), Chapter 3 (MWCs AB, 21) and Exhibit

	(PG&E-4), Chapter 2A.
a) Employee Engagement, Training, and Tools	b) Employee Engagement, Training, and Tools was not part of the 2017 RAMP Report as CWSP had not yet been developed at the time. c) Details describing the scope of this program are discussed in Exhibit (PG&E-8), Chapter 6 and Exhibit (PG&E-4), Chapter 2A.
a) CWSP PMO	b) CWSP PMO was not part of the 2017 RAMP Report as CWSP had not yet been developed at the time. c) Details describing the scope of this program are discussed in Exhibit (PG&E-4), Chapter 18 (MWCs AB, 21) and Exhibit (PG&E-4), Chapter 2A.

Gas Operations Measurement and Control Failure - Release of Gas with Ignition Downstream RAMP Risk (Christine Cowsert)

Part a) Response	Part b) and c) Response
Overpressure Protection	b) This gas distribution portion of the Station Overpressure Protection (OPP) Program was not a part of the 2017 RAMP Report as the scope of the program for distribution assets was unknown at the time. c) The gas distribution M&C Station OPP Enhancements Program is a new program to prevent large OP events due to equipment failure at gas distribution regulator stations. The OPP Enhancements Program addresses the potential for regulation equipment-related failures or malfunctions. While the OPP mitigation actions are primarily aimed at equipment issues, the actions may also mitigate the potential for incorrect operations and construction related threats that may contribute to regulation station operational issues. For details on this program, please see Exhibit (PG&E-3), Chapter 5.

Information Technology Cyber Attack RAMP Risk (Joe Sagona)

Part a) Response	Part b) and c) Response
Integrated Grid Platform (IGP) Advanced Persistent Threat (APT) and Advanced Security Analytics	b) IGP: At the time of the 2017 RAMP Report, IGP had not been identified as a top PG&E safety risk, nor was it included in the Cyber-Attack risk. APT and Advanced Analytics: This is a recently introduced mitigation, and capabilities enabled by this project have been implemented by other utilities. c) IGP: Details describing the scope of this program are discussed in Exhibit (PG&E-4), Chapter 19 and Exhibit (PG&E-7), Chapter 9, pp. 9-29 through 9-30. APT and Advanced Analytics: Details describing the scope of this program are discussed in Exhibit (PG&E-7), Chapter 9, pp. 9-30.

PACIFIC GAS AND ELECTRIC COMPANY
2020 General Rate Case Phase I
Application 18-12-009
Data Response

PG&E Data Request No.:	PubAdv_031-Q04		
PG&E File Name:	GRC-2020-PhI_DR_PubAdv_031-Q04		
Request Date:	January 23, 2019	Requester DR No.:	031
Date Sent:	February 6, 2019	Requesting Party:	Public Advocates Office
PG&E Witness:	Stephen Cairns	Requester:	Pui-Wa Li

SUBJECT: EXHIBIT (PG&E-2) – EXCEL FILES SUPPORTING EXHIBIT (PG&E-2)

QUESTION 04

Please list out the updates or changes to the risk model inputs that PG&E has made since the commencement of I.17-11-003.

Specifically, please compare—item by item—the risk model inputs filed as part of I.17-11-003 with those filed as part of A.18-12-009.

ANSWER 04

Please see attachment “GRC-2020-Ph1_DR_PubAdv_031-Q04Atch01.” Please note that the tab for the changed Records Management risk inputs “20-RM errata” reflects errata that has not yet been formally submitted.

SCE Response to Data Request CalAdvocates DR-02 Question 7

Southern California Edison
I.18-11-006 – SCE 2018 RAMP

DATA REQUEST SET CalPA-SCE-02

To: CalPA
Prepared by: Miriam Day
Job Title: Facilities Construction Project Manager
Received Date: 5/2/2019

Response Date: 5/15/2019

Question 07:
For SCE's RAMP report Chapter 4: Building Safety, please explain why SCE considered mitigation M1: Fire Life Safety Portfolio Assessment, in its proposed plan and both of its alternate plans despite the mitigation having a relatively low RSE of 0.0001.

Response to Question 07:

RSE was only one factor that SCE used to inform the selection of mitigations in each plan. An important consideration was the fact that jurisdictions are increasing the requirement levels of Fire Life Safety Systems for new constructions for buildings of similar size and height, making this a best practice.

Despite having a relatively low RSE score, SCE considered proactive due diligence and assessment of the status of building life-safety systems programs to be reasonable, and integral for commencing the formulation of any plan going forward.

The Fire Life Safety program is focused on mitigating risks associated with the 40 out of 170 SCE buildings that are currently grandfathered and in compliance, but are operating without Fire Life Safety systems, which are assumed to be addressed at a pace of two to four per year.

Since only a subset of the 170 buildings are expected to be selected for implementing Fire Life Safety changes with a nominal cost of $5.9M relative to the value of the portfolio, the upgrade benefit per building (which is measured in terms of an incremental contribution to the overall risk reduction across the entire portfolio) leads to a relatively low RSE score.

SCE Response to Data Request CalAdvocates DR-02 Question 8

Southern California Edison
I.18-11-006 – SCE 2018 RAMP

DATA REQUEST SET C a l P A - S C E - 0 2

To: CalPA
Prepared by: Miriam Day
Job Title: Facilities Construction Project Manager
Received Date: 5/2/2019

Response Date: 5/20/2019

Question 08:
For SCE's RAMP report Chapter 4: Building Safety, SCE only evaluates mitigation M4: Worker Relocation, in tandem with mitigation M5: Building Replacement, in Alternative Plan #1. However, M4 has a relatively high RSE of 0.127, whereas M5 has a relatively low RSE of 0.001. Please explain why SCE did not evaluate an alternate plan that would implement M4, without M5.

Response to Question 08:

For purposes of this RAMP report, SCE evaluated the risk benefits of three distinct mitigation plans. SCE includes all controls in each of the three options for this chapter, but varies which mitigations each plan will contain, in part to understand the different risk benefits of each plan when considering different packages of mitigations. In this case, SCE considered a scenario (Alternative Mitigation Plan #1) where we would both relocate workers and replace building(s).

In some cases, it is more feasible to permanently relocate workers to different locations. In others, such as geographically-dependent garages, service centers, maintenance and test buildings, and substations, it can be more difficult to relocate work. As such, implementing M4 alone presents some feasibility challenges, since there are not readily available locations to move the workers, and/or moving them would constrain existing building space that could be used for higher-value purposes. Consequently, we built this plan to consider both approaches.

M5 low RSE is derived from the high cost of building replacement, which does not offer significant risk reduction per dollar spend. However, when combined with the relocation of workers (M4), the Alternative Mitigation Plan #1 provides an additional 14% mitigated risk reduction (MRR) compared to the proposed plan. Due to the interrelationship of M4 and M5, these two mitigation efforts are considered and presented collectively.

In managing the safety and reliability of our facilities going forward, SCE will continue to consider feasible and cost-effective options. This may include relocating workers (M4), independent of, or in concert with, replacing buildings (M5).

5 Advantages of Face-to-Face Training

5 Advantages of Face-to-Face Training

By **Guest Contributor** - 12/04/2015

Recently there has been a boom in the e-learning industry because its ease of use, availability and because technology is always on the rise. Its credibility in terms of qualifications has been a deal breaker in some instances where "having an online degree from an unaccredited school is a sure way to get a resume discarded".

It is true that online training is more readily available and perhaps more convenient but in terms of efficiently learning, it may not be the best way to go yet. Face-to-face training is the traditional way and still has its strong foundations embedded into the learning process for many companies and institutions because of its clear advantages. Here are some of them:

1. **Networking**

This is a key aspect, networking is almost like the bread and butter of business. Although e-learning courses and do have networking potential via chat rooms, messages and emails; it simply is not as effective as having a real life human interaction with another person where you exchange hand shakes and conversation. This method is more significant and is a huge bonus which you can get from face-to-face training and means you will network more efficiently which in itself has a lot of benefits.

2. **Engagement and Focus**

E-learning is essentially just watching a video stream, playback or reading texts, presentations and such, the nature of it allows many distractions to easily affect the user unless self-discipline and focus is implemented and reinforced to ensure the learner is paying full attention at all times.

Many people using e-learning will end up subconsciously 'multi-tasking' because they will be doing something else while doing the course and it affects what they actually gain from the e-course.

With face-to-training, you are usually in a classroom with the teacher, where many teachers will implement strategies to keep you involved and engaged as possible because it retains your attention and will most definitely encourage better results.

3. **Adaptability – keyword "customized training courses"**

Many instructors and companies now offer customised training courses, which is a great initiative because it allows delegates to specifically learn what they want to learn, which ends up being cost effective and keeps the customer happy because many of them will not want to learn the excess information that does not apply to them, at the same time they will be unhappy if they didn't learn what they wanted to learn. Courses that operate face-to-face have the amazing option to be adapted to the learner's needs when needed where as e-learning simply just offers set options.

4. **Discussion**

An important factor we forget about e-learning is the sheer importance of human interaction as mentioned before. A lot of great things can come by being in a room with other people wanting to learn, such as detailed discussions and debates regarding subject topics where you may even learn from other people and take in viewpoints that you haven't considered yet. It is easier to interact and meet new people from inside or outside of work when you have a common ground.

5. **Ability to have 1-to-1 if any problem arrises**

Every learner will be different, some are very independent in the sense that if they have a problem, they will eventually solve it themselves with no problem. However there are a lot of learners who need to be shown or have something explained because they do not understand it.

If something goes wrong while e-learning, whether it be something as simple as not knowing the meaning of the word, phrase or just simply not understanding the concept of something, it may be a long-winded process to find the answer. This basically forces you to be independent if something goes wrong which is bad because if you happen to be one of those people who need to have something explained to, what would you do then?

If a problem arises when you are in a face-to-face course, you can simply ask the instructor to explain it better so you know what is going on.

To conclude, these were just some points as to why face-to-face training has many clear advantages over e-learning but e-learning is still a newly formed method and will continue to grow and maybe will improve to such a point where it succeeds compared to face-to-face training.

This article was written by the London Management Centre, a consultancy company focusing on training courses in London in fields such as business, management and marketing. To continue the discussion, we invite you to follow the London Management Centre on LinkedIn.

Related Posts:

CalAdvocates-SA-38

Key Benefits of Providing Health and Safety Training for Employees

Blog

Wise Global Training Ltd

Key Benefits of Providing Health And Safety Training For Employees

CalAdvocates-SA-40

No matter how small or large a company is, workers in all fields of industry face workplace dangers that can threaten their health and safety. In some industries, such as in the mining and oil industries, the dangers can be evident: exposure to harmful chemicals, fires, explosions and breakdown of machinery are just some of the health risk that workers in these fields face every single working day. For other fields of business, however, the dangers may not be as obvious: working in an office or a restaurant may seem harmless, but poor ergonomics, food contamination and psychological stress can also cause health problems that can hamper productivity. Because hazards are present in all types of industries, it's essential for companies to provide health and safety training for their workers and to update this knowledge on a regular basis.

Educating workers on the basics of occupational health and safety can help reduce workplace accidents and injuries, saving companies from costly legal battles with employees and lifelong support for their families. In addition, prioritising the safety of your personnel can keep them from leaving the job because of work-related illness, keeping financial losses secondary to lack of skilled workers at a minimum.

Apart from the obvious legal and financial benefits that come with giving health and safety instruction to employees, businesses can also enjoy enhanced productivity and satisfaction among personnel by keeping the workplace safe. It's important to note that employees in a safe work environment can focus better on their tasks, simply because they do not have to worry as

CalAdvocates-SA-41

Employees who are confident of their safety at work also tend to be more satisfied with their employers — and it goes without saying that this increase in employee morale will also boost productivity. Employers who take measures to keep their workers safe are also more likely to earn the loyalty of employees, and as such, highly valuable skilled workers are less likely to leave and transfer to other companies.

There are various certificate courses that workers in any industry can avail of. For those who simply want a broad understanding of health and safety principles, a suitable first step is the NEBOSH General Certificate. This course can be taken by workers in all industries and it also serves as an introduction to more specialised safety training, such as the NEBOSH Oil and Gas Certificate. Other courses for occupational health and safety include courses from the Institution of Occupational Safety and Health (IOSH Managing Safely and IOSH Working Safely) as well as courses from the Chartered Institute of Environmental Health (CIEH).

If you have any questions, just contact us so we can help.

Questions? We are happy to help! Just fill out the form below and we'll get back to you shortly.

First Name *

Email *

Let us know how we can help! *

Privacy Policy *

CalAdvocates-SA-42

CPUC-CalFire MOU

MEMORANDUM OF UNDERSTANDING
BETWEEN THE
CALIFORNIA PUBLIC UTILITIES COMMISSION
AND THE
CALIFORNIA DEPARTMENT OF FORESTRY AND FIRE PROTECTION

The California Public Utilities Commission (CPUC) and California Department of Forestry and Fire Protection (CAL FIRE) (collectively the Parties) enter into this Memorandum of Understanding (MOU) to cooperatively develop consistent approaches to forest management, safety and energy programs.

ROLES AND RESPONSIBILTIES

CAL FIRE is charged with the fire prevention, protection, and stewardship of over 31million acres of California's privately-owned wildlands. CAL FIRE answers the call to more than 350,000 emergencies each year such as fires, medical aids, hazardous material spills, search and rescue missions, train derailments, and earthquakes. CAL FIRE is responsible for fire and life safety code review of all State-owned and leased buildings, the training certification of firefighters, and the inspection of 6,500 miles of intrastate hazardous liquid pipelines. In addition, CAL FIRE provides varied emergency services to approximately 150 local cities, counties, and fire districts via cooperative contracts.

The CPUC ensures that regulated services are delivered in a safe, reliable manner. CPUC regulations are designed to protect the public from potential hazards, including fires, which may be caused from electric utility transmission or distribution lines, or communications infrastructure providers' facilities in proximity to the electric overhead transmission or distribution lines. The Commission's current General Orders 95, 128, and 165 are designed to promote the safe installation and operation of electric utility and communications infrastructure facilities, and provide the minimum safety requirements which the utilities are supposed to supplement with additional safety precautions when operations and local conditions warrant.

SHARED PRIORITIES

The following priorities are shared by the CPUC and CAL FIRE for effective communication and coordination:

1. Work together to develop consistent approaches to forest management, wildfire prevention, public safety, and energy programs.
2. Develop management alignment on key policy issues.

3. Develop a statewide biomass/bioenergy/biofuel strategy to ensure cost effective methods exists to deliver fuel to biomass/biofuel facilities.
4. Assist one another in preparing for, responding to, and mitigating the effects of wildfires.
5. Deepen awareness of the requirements and goals of each other's programs.
6. Create an Interagency Fire Safety Working Group to vet ideas and develop programmatic solutions to shared goals in the interest of fire safety and resource protection.

Immediate-Term Goals:

In order to achieve optimal results for the shared priorities, the Parties' immediate term goals are as follows:

1. Develop a shared understanding of the use of fire mapping, including enhanced enforcement of the CPUC's General Order 95.
2. Develop a shared understanding of utility deployment timelines, procedures, and operations during a wildfire event, including enhanced enforcement of CPUC General Order 166. Ensure utilities establish significant base camps and are a major presence at incident sites of major fires.
3. Enhance the Parties' communication during and following a wildfire event. The CPUC can serve as a link between CAL FIRE and utilities during an event.
4. Coordinate on a range of resource management issues, fuels treatments, tree mortality, and bark beetle infestation. Jointly identify any mitigation measures that the utilities need to take in response to the tree mortality crisis.
5. Initiate the process for utilities to develop and submit fire hazard prevention plans required by SB 1028. Work together on identifying the requirements for fire hazard prevention plans and communicating these requirements to the utilities. Develop a process for review of fire hazard prevention plans.
6. Provide complementary resources in the areas of risk mitigation, risk management, and investigative relationships between CAL FIRE and the CPUC relating to suspected utility involved fire events.
7. Share best practices related to regulation, inspection, and overall safety of hazardous liquid and gas pipeline systems.

CAL FIRE RESPONSIBILITIES

In order to achieve optimal results for the shared priorities, CAL FIRE will perform the activities and functions summarized below.

1. Upon request, review utility wildfire mitigation plans in accordance with Public Utilities Code Sections 8385 to 8387. Assist CPUC in developing criteria and standards to be used in wildfire mitigation plans.
2. Identify and develop contracting requirements necessary for the completion of Fire Map 2 and the establishment of the CPUC Wildfire Mitigation Section in accordance with SB 1028.
   a. Participate in the Technical Review Team (as defined in the CPUC's Fire Map 2 Work Plan Decision 17-01-009).
   b. Assess, evaluate, and provide formal feedback via public comments or reports on future Party-submitted mapping proposals regarding physical mapping changes and challenges and/or adjustments to existing mapping methodologies.
   c. Assess, evaluate, and provide formal feedback via public comments on utility SB 1028 wildfire mitigation plans and utility vegetation management plans.
3. Provide subject matter expertise in mechanical engineering, utility design and testing, and wildland fire risk analysis to the CPUC to advise on wildfire mitigation program management, audit schedule, mitigation plan details, and enforcement. In addition, this liaison(s) will interface with CPUC staff to assist with technical fire science/behavior assessment and allocation of resources.
4. Participate in identifying best practices of design and operation of utility systems for the purposes of fire mitigation.
5. Provide CPUC staff with CAL FIRE operations documentation, including current CAL FIRE structure, operations model, field operations, investigation procedures, and utility/local community outreach efforts/relationships and also be available for follow-up regarding briefing documentation.
6. Provide safety training to select CPUC personnel in order to enhance the CPUC's ability to coordinate with CAL FIRE and/or utilities in the vicinity of a wildfire event.

CPUC RESPONSIBILITIES

In order to achieve optimal results for the shared priorities, the CPUC will perform the activities and functions summarized below.

1. Oversee utility implementation of wildfire mitigation plans and ensure adherence to best practices identified by CAL FIRE.
2. Adopt risk-based regulations that are in alignment with Fire Map 2 through the CPUC formal process.
3. Perform compliance and enforcement activities pertaining to adopted rules related to fire mitigation and emergency response.

4. Use CPUC regulatory authority to assist CAL FIRE to resolve issues with utilities.
5. Dedicate staff to work with CAL FIRE and ensure staff participation in training.
6. Provide funding as necessary to support CAL FIRE's efforts to meet CPUC assistance requests.
7. Assist CAL FIRE in areas of CPUC expertise.
8. Track and report vegetation management clearance activities on an annual basis to CAL FIRE and the California Board of Forestry and Fire Protection.
9. Fund applied research to examine the effectiveness of vegetation clearance and other activities in wildlife mitigation plans designed to reduce wildfire risk. Fund research to refine fire models and data layers that are used to develop Fire Map 2.

PROTECTION OF CONFIDENTIAL INFORMATION

"Confidential Information" includes information obtained pursuant to California Public Utilities Code section 583, records exempt from public disclosure under the California Public Records Act (Government Code sections 6250, et seq.), or written or verbal information that is designated by the Parties to be exempt, prohibited, or privileged from disclosure by State or federal law.

The Parties shall take all necessary measures to protect Confidential Information and, consistent with the Public Records Act and any other laws requiring disclosure, treat the shared Confidential Information as confidential. The Parties shall impose all the requirements of this MOU on all of their respective officers, members, employees and agents with access to Confidential Information. Any Confidential Information obtained by the Parties shall only be used for purposes which are consistent with existing law.

All Confidential Information provided to the Parties pursuant to this MOU shall be subject to Government Code Section 6254.5, subdivision (e), which exempts from public disclosure under the California Public Records Act, confidential records that one State or local agency has provided to another State or local agency pursuant to an agreement that the latter will treat the disclosed records as confidential.

SCOPE

This MOU is made for the sole benefit of CAL FIRE and CPUC, and no other person or entity shall have any rights or remedies under or by reason of this MOU. Nothing in this MOU may be the basis of any third-party challenges or appeals. Nothing in this MOU creates any rights, remedies, or causes of action in any person or entity not party to this MOU.

CAL FIRE and CPUC each retain all rights, responsibilities, and authorities provided for by law. Nothing in this MOU delegates any rights, responsibilities, or authorities provided by law to either Party. Nothing in this MOU delegates or otherwise prevents, compromises, or precludes each Party from exercising all rights, responsibilities, or authorities provided by law.

Both parties will meet and coordinate progress regarding the MOU on an annual basis, or as mutually agreed upon by the parties.

APPROVAL

This MOU is effective upon completion of the signatures listed below. This MOU shall not be modified except by a written agreement signed by authorized representatives of the Parties.

This MOU shall continue unless or until either Party to the MOU determines that the MOU should be terminated. Unless otherwise provided for by the written agreement of both of the Parties, unilateral termination of the MOU shall be effected no sooner than 60 days from the date either party provides written notice of its intent to terminate the MOU. Termination of this MOU shall not affect the obligation of the parties to maintain the confidentiality of information pursuant to this MOU.

CALIFORNIA PUBLIC UTILITIES COMMISSION:

Timothy J Sullivan — August 18, 2017

TIMOTHY J. SULLIVAN — August 18, 2017
Executive Director

CALIFORNIA DEPARTMENT OF FORESTRY AND FIRE PROTECTION:

Ken Pimlott

KEN PIMLOTT — August 23, 2017
Director

Cal Advocates Comments on PG&E 2017 RAMP Report Excerpts (pp. 4, 5, 26, 40)

BEFORE THE PUBLIC UTILITIES COMMISSION
OF THE STATE OF CALIFORNIA

FILED
05/10/18
04:59 PM

Order Instituting Investigation into the November 2017 Submission of Pacific Gas and Electric Company's Risk Assessment and Mitigation Phase.	Investigation 17-11-003 (Filed November 9, 2017)

COMMENTS OF THE OFFICE OF RATEPAYER ADVOCATES ON NOVEMBER 2017 SUBMISSION OF PACIFIC GAS & ELECTRIC COMPANY'S RISK ASSESSMENT AND MITIGATION PHASE

LAURA TUDISCO
Attorney for the
Office of Ratepayer Advocates

California Public Utilities Commission
505 Van Ness Avenue
San Francisco, CA 94102
Telephone: (415) 703-2164
Email: ljt@cpuc.ca.gov

NUSRAT MOLLA
Utilities Engineer for the
Office of Ratepayer Advocates

California Public Utilities Commission
505 Van Ness Avenue
San Francisco, CA 94102
Telephone: (415) 703-2097
Email: nusrat.molla@cpuc.ca.gov

ALAN BACH
Utilities Engineer for the
Office of Ratepayer Advocates

California Public Utilities Commission
505 Van Ness Avenue
San Francisco, CA 94102
Telephone: (415) 703-3449
Email: alan.bach@cpuc.ca.gov

NATHANIEL SKINNER
Program/Project Supervisor for the
Office of Ratepayer Advocates

California Public Utilities Commission
505 Van Ness Avenue
San Francisco, CA 94102
Telephone: (415) 703-1393
Email: nws@cpuc.ca.gov

May 10, 2018

5. Granularity of Incident Driver Data

Risk incidents frequently have multiple factors that contribute to the incident occurrence,[6] and cannot be solely attributed to a single driver. PG&E should ensure that the incident data used in its RAMP models has the granularity to assign percentage attribution of an incident to multiple drivers.

6. Granularity of Exposure Units

As demonstrated by certain risks (for example, Chapter 10 - Transmission Overhead Conductor), risk exposure may not be evenly distributed throughout a system, and certain portions of the exposure may represent a disproportionate amount of the risk. Identifying the portions of exposure that represent higher risk can be important in identifying the proper target for mitigations. The CPUC Safety and Enforcement Division's (SED) Risk and Safety Aspects of Risk Assessment and Mitigation Phase Report of Pacific Gas & Electric Company Investigation 17-11-003 (SED Report) noted that PG&E's exposure unit for Chapter 1: Transmission Pipeline Rupture with Ignition is simply miles of transmission pipelines without differentiating characteristics of such pipe, despite the fact that "pipeline diameter and operator pressure play a significant role in determining the potential consequence."[7] Since PG&E is already indirectly required by federal regulations to mitigate risk on gas pipelines based on population density,[8] PG&E could, by incorporating population density exposure granularity into its risk consequence and mitigation effectiveness calculations, preferentially mitigate risk at high population density areas.

---

[6] For example, Transmission Pipeline Rupture with Ignition can be caused by equipment failure, external corrosion, or incorrect operations, to name a few. In the National Transportation Safety Board's (NTSB) Pipeline Accident Report 11-01 of PG&E's San Bruno Line 132 rupture, the NTSB attributed the rupture to a welding defect, but the event was catalyzed by lack of proper communication of risks (incorrect operations) while performing equipment replacement work. See page B-20 for an example risk bowtie.

[7] SED Report at p. 16.

[8] Through more stringent safety requirements based on "class locations", as defined by Title 49 Code of Federal Regulations §192.5. Examples where PG&E must consider class location, and thus indirectly population density, for pipeline safety include §192.503(c): General Requirements [for Pipeline Testing], §192.611: Change in class location: Confirmation or revision of maximum allowable operating pressure, and §192.705: Transmission lines: Patrolling.

Such quantification of consequence based on population density would be prudent for all physical asset-based risks, and not just gas pipeline risks.[9]

While ORA understands PG&E may not currently have enough data to further categorize risks into more the more granular exposure units recommended in this section, PG&E should ensure data collection of these risks allow for such greater exposure granularity in the future.

7. Model Validation and Calibration

As more PG&E-specific data regarding the 22 risks is gathered, PG&E should employ validation techniques to ensure the RAMP model is producing reasonably-accurate results. Based on the validation, the model should be recalibrated accordingly. While multiple risk chapters in the report (e.g. Chapters 1, 4, 6, and 11) have already stated the need for model calibration, future RAMP reports should make it explicitly clear that such calibration is necessary for all chapters. Furthermore, validation will ensure the model is producing reasonable risk estimations in the first place, and whether changes to the model's structure are necessary for more accurate results.

8. Give PG&E-Specific Data Greater Weight

PG&E-specific data should be more pertinent to predicting PG&E's future risk than more general data. PG&E, therefore, should give data specific to its own facilities greater weight than data from more general sources, assuming that PG&E has properly vetted the quality of its data and has sufficient quantity of data.

B. Mitigation and Risk Spend Efficiency (RSE) Calculations

1. Calculation of RSE Scores

In its RAMP filing, PG&E provided risk reduction scores, which represent the total reduction in the MARS due to a mitigation, and RSEs, which represent the MARS reduction per dollar spent on a mitigation, based on bundled mitigations. The risk reductions for each bundle is determined by simply adding the risk reductions and costs associated with each individual mitigation. However, this approach does not account for any potential synergies or overlaps that may exist among individual mitigations in reducing

[9] The current method for quantifying the consequence of Wildfire Risk based on the Fire Threat Map is also an example of an appropriate method for accounting for areas of disproportionate risk.

Due to PG&E's data for the fatality consequence from this risk stemming from 3 instances of fatalities, and that this fatality consequence is quite significant in that it makes up over a third of the Tail Average MARS score for this risk, ORA's comments on this chapter's need to manage uncertainty are reflected in General Comments Section A.4 above.

ORA supports the separation of this risk into wire down and 3rd party contact categories, due to the lack of interdependence between the two.

K. Wildfire

The Wildfire risk has a Tail Average MARS of 257.58, ranking it 5th among all risks. The total spend proposed plan is $797,683,138 from 2017 to 2022. The proposed plan results in a risk score reduction of 76.97 MARS units, and a total RSE of 0.097 MARS Units/million dollars spent. This risk is defined as PG&E assets initiating a wildland fire that endangers public or private property, sensitive lands, and/or leads to long-duration service outages.

This chapter has the strength of drawing on a large body of data regarding wildfires in California to inform its estimate of the risk consequences and mitigation effectiveness, rather than relying solely on SME data. In addition, ORA supports the use of multipliers[52] in calculating mitigation effectiveness in areas with increased fire risk or vegetation contact, and encourages developing further granularity in future iterations of the model.

The alternatives presented in this chapter exemplify the issues with the proposal of alternatives in this report. Contact with vegetation is the most significant risk driver of wildfire ignitions initiated by PG&E assets in the Fire Index Area.[53] Yet, Alternative 1 excludes mitigations like "Fuel Reduction and Powerline Corridor Management" and "Overhang Clearing" that aim to reduce the risk of ignitions caused by contact with vegetation risk driver.[54] Unsurprisingly, this alternative was found to not provide sufficient

---

[52] Some of the figures shown in the "Justifications" on WP 11-5 to WP 11-30 are incorrect. Per ORA's conversation with PG&E witnesses on April 9, 2018, it is ORA's understanding that PG&E will submit errata with corrected multipliers.

[53] PG&E RAMP Report, Risk Bowtie at p. 11-6.

[54] PG&E RAMP Report at p. 11-18.

mitigation strategy that the cross-cutting risk model is designed for.

V. CONCLUSION

ORA agrees with SED and other parties that the RAMP is an evolving process that should benefit from continued learning and improvement. ORA recognizes and appreciates the efforts of PG&E to prepare this first-ever RAMP filing. In particular, PG&E has recognized the shortcomings of its analyses and identifying steps to improve them. In summary, ORA has the following suggestions for PG&E's future RAMP reports:

- Remove Trust as a consequence category, and reweight the consequence categories so that the weighting of natural units is consistent;
- Increase the granularity of incident drivers and exposure units to better account for heterogeneous risk profiles;
- Improve model inputs, give greater weight to vetted PG&E-specific data to ensure that model outputs properly reflect PG&E's experience, and utilize methods to account for data uncertainty;
- Improve the quality of the alternative mitigation plans proposed, ensuring that they are potentially desirable and feasible;
- Adjust calculation of RSE to account for potential interactions between mitigations, and mitigations for which benefits extend beyond the rate case period;
- Improve the clarity by providing values such as the total and annual risk reduction of mitigations, clarifying drivers for cross-cutting risks, and being consistent in which timeframe the RSE and the total cost of mitigations plans are presented;
- Move towards being able to optimize spending across risks, including the identification of risk tolerances, the calculation of RSE on an enterprise level, and the consideration of the EV MARS in addition to the TA MARS in prioritizing risks.

ORA's comments, particularly those regarding the quality of model inputs, increased exposure granularity, and optimization across risks, are intended to be long-term objectives for the model as PG&E obtains more robust data and develops its expertise in risk modeling. Some recommendations, including those regarding improved RSE

SCE Response to Data Request CalAdvocates DR-02 Question 9

Southern California Edison
I.18-11-006 – SCE 2018 RAMP

DATA REQUEST SET C a l P A - S C E - 0 2

To: CalPA
Prepared by: Eghosa Obasohan
Job Title: Advisor
Received Date: 5/2/2019

Response Date: 5/15/2019

Question 09:
For SCE's RAMP report Chapter 12: Climate Change, please state what controls and mitigations SCE currently plans to implement for beyond the 2018-2023 time period, i.e. what climate change controls and mitigations SCE currently plans to implement for 2024-2050.

Response to Question 09:

SCE has not developed a detailed plan for specific controls and mitigations that will be implemented over the 2024-2050 time period. SCE will continue to evaluate the impacts of severe weather and climate change, as indicated in the RAMP chapter. Some key considerations are listed below:

- We are in a foundational stage. We have continued to work on analyzing the climate projection models available through Cal-Adapt and other sources. Currently, we think that the available climate science is fairly good directionally, but more site-specific data is required to help inform specific actions.
- Continued efforts will examine how we can couple historical weather data, site-specific analysis, and climate model projections to understand impacts and possible investment options. We see this in the near-term as incremental efforts to existing work
- We recognize the need for future mitigations to continue to be collaborative with communities. This is an opportunity to work together with stakeholders, since dealing with climate change is a shared responsibility
- In addition to the controls and measures already identified, subject to the outcome of phase 1 of the Commission's Climate Adaptation OIR, SCE may add or refine efforts based on the Commission's adopted definitions of Climate Adaptation and vulnerable communities, and the decision-making framework or guidance developed in the OIR

As discussed in the Climate Change RAMP Chapter, currently SCE has the following controls and mitigations, which are also contemplated in the longer-term period of 2024-2050.

Controls

- C1 Emergency Management
- C2 Fire Management

C1 & C2 have been in existence for some time and will continue to address the Company's need to deal with emergency response and restoration, not just related to climate change impacts. As weather extremes continue to impact the communities and customers we serve, we aim to continue to make sure that we have proper response procedures to deal with changing severe or extreme events.

- C3 Climate adaptation and resiliency community grants

There are already philanthropic and public engagement efforts with the communities we serve to work on solutions to address climate change adaptation. We anticipate continued work to collaborate and work on possible solutions together on this shared responsibility

Mitigations

- M1 Climate Adaptation and Severe Weather Program

SCE currently has a Hazard Assessment and Mitigation Program; the program will continue to assess and mitigate natural hazards and man-made threats that may impact our ability to provide adequate service to the customers and communities we are privileged to serve. This will include specifically looking at severe and extreme weather and gradual conditions that relate to climate change that may need action.

- M2A Situational Awareness, Monitoring & Analytics

Monitoring and more advanced modeling of hazards will be developed in the 2018-23 timeframe. This will continue as we consistently seek to improve our monitoring abilities and modeling approaches as hazards and threats evolve or emerge.

Please note that when SCE files its 2021 GRC application later this year, we intend to include updated plans for climate change controls and mitigations discussed in this RAMP chapter for the years 2019-2023.

Edison fined for its handling of nuke canisters

Edison fined for its handling of nuke canisters

Rob Nikolewski, San Diego Union-Tribune Published 3:54 p.m. PT March 26, 2019

The U.S. Nuclear Regulatory Commission hit Southern California Edison on Monday with $116,000 in civil penalties following an incident last August in which a 50-ton canister filled with nuclear waste was left suspended for 45 minutes about 18 feet off the floor of a storage cavity at the San Onofre Nuclear Generating Station.

In addition, the NRC revealed that Edison officials last week began inspecting via remote video a “representative sample” of canisters already lowered into the newly constructed “dry storage” facility, looking for scratches on them.

More Southern California Southern California power coverage:

- Both ignition points of Thomas Fire now blamed on power equipment (/story/news/local/communities/ojai/2019/03/20/investigators-release-cause-koenigstein-road-fire/3229407002/)
- Southern California Edison's competitor is up and running (/story/news/local/communities/ventura/2019/02/09/southern-california-edisons-competitor-clean-power-alliance-community-choice-aggregator/2744796002/)
- Counties say power shutoffs take toll on safety, finances (/story/news/local/2019/01/10/southern-california-edison-pg-e-power-shutoffs-wildfires-public-safety/2486196002/)

NRC officials said they will not give Edison the OK to resume transferring more canisters until the inspection data have been analyzed. The NRC did not indicate how long that will take.

As for the Aug. 3 incident in which the canister was accidentally left on the inner-ring of a storage vault, the NRC cited Edison for two violations.

Saying the incident on Aug. 3 “could have resulted in a significant safety consequence,” the independent federal agency in charge of protecting public health and safety related to nuclear energy fined the utility for failing to make sure the heavy canister was properly supported.

In this June 7, 2013, file photo, surfers stand in water in front of the shuttered San Onofre Nuclear Generating Station. The Nuclear Regulatory Commission is fining Southern California Edison $116,000 for violations in its handling of nuclear canisters at the facility. *(Photo: AP FILE PHOTO)*

The NRC also chided Edison officials for not reporting the incident within 24 hours but did not assign a civil penalty for that violation.

“SCE management failed to establish a rigorous process to ensure adequate procedures, training and oversight guidance,” said Lee Brookhart, a senior inspector at the NRC, during a webinar from the agency’s branch office in Arlington, Texas.

An Edison spokesman said the utility, which oversees the plant that goes by the nickname SONGS, will not contest the fine, which shareholders — not ratepayers — will pay.

“The event should not have happened and as the licensee we take full responsibility,” said SCE media relations manager John Dobken.

Edwin Lyman, acting director of the Nuclear Safety Project for the Union of Concerned Scientists, said he was heartened to see the NRC issue a civil penalty.

“I think this should be a wake-up call, not just to SONGS and Holtec, but across the whole industry that they need to maintain very rigorous inspections, training and some oversight of their own operations,” Lyman said.

Holtec International, based in New Jersey, designed the dry storage system and was contracted by Edison to oversee the transfer of canisters from “wet storage” pools at the plant to the dry storage location — a journey in which a single canister is carried about 1,500 feet via heavy equipment traveling about 3 mph.

Vowing to avoid a repeat of the incident, Edison has instituted a series of changes to create a “more robust program” for future transfers. The utility said it has beefed up training, procedures and oversight. Additional equipment, including an overhead camera and an alarm system, have also been added.

First revealed to the public by a worker at the plant, the August incident occurred when workers thought the canister had been completely lowered into the storage vault but it had not. Instead, it came to rest near the top of the cavity.

What’s more, the heavy canister was not supported by the rigging and lifting equipment that includes two yellow slings designed to complete the transfer operation.

Within a few minutes, the mistake was noticed and the canister was eventually lowered but not before it was left unsupported for about 45 minutes.

Officials with the two companies said workers and the public were not in danger, and even if the canister had fallen 18 feet, the “robust” design of the canister would have prevented any radiological release.

At Monday’s webinar, the NRC said it conducted an independent review of what could happen if a canister fell 25 feet. It concluded the canister itself would remain intact but the fuel assemblies inside the canister would sustain damage.

“Even so,” Brookhart said, “the canister would still provide structural thermal, shielding and critical control functions after the drop.”

Shortly after Aug. 3, Edison officials described the incident as a “near-miss” and suspended future transfers at the plant. Last September, the NRC launched a weeklong “special inspection” into what happened.

In this June 30, 2011 file photo, people walk on the sand near the shuttered San Onofre nuclear power plant. *(Photo: AP FILE PHOTO)*

According to the inspectors, on Aug. 3 the crane operator of the transporter that moves the heavy canisters had never before completed a downloading operation. It also marked the first time the “rigger/spotter” — who watches the top of the canister to make sure it is successfully lowered — had attempted a downloading.

The canister lowered on Aug. 3 marked the 29th of 73 canisters moved to the new dry storage facility. Forty-four others are scheduled to eventually be transferred.

Three canisters were inspected last week, Dobken said — the canister downloaded on Aug. 3, another lowered last July 22 that got stuck for a few minutes but was fully supported by the rigging and equipment, and a third that was successfully placed into a cavity on March 23, 2018.

Dobken said a robot that can cover 92 percent of the canister surface is providing inspection data that is still in the process of being reviewed by the NRC.

Charles Langley, executive director of San Diego-based Public Watchdogs, said the $116,000 in fines were “comparatively paltry” considering the billions collected from ratepayers for SONGS over the decades and “will pave the way to additional safety lapses in the future.”

Rep. Mike Levin, D-San Juan Capistrano, said the NRC is not doing enough to ensure safety.

“I strongly urge the NRC to consider additional steps to prevent future safety violations,” Levin said in an email, “and I hope that its ongoing investigation into the gouging of Holtec’s canisters is thorough and conducted with integrity.”

San Diego attorney Michael Aguirre recently filed a federal lawsuit against the NRC, complaining the federal agency “has engaged in stonewall tactics” in turning over responses to Freedom of Information Act requests for documents related to problems during the transfer process at SONGS.

“The NRC is not making sure in the interim that the waste (at SONGS) is being carefully stored and organized,” Aguirre said after the webinar. “They’re acting more like an advocate for Southern California Edison than a regulator.”

Linda Howell, deputy director of the division of Nuclear Materials Safety, pushed back on the notion that the NRC is protecting SCE.

“There was absolutely no work on the part of the NRC to cover this incident up,” she said, citing the initiation of the inspection process at SONGS that is still ongoing and subsequent reports that have been made public.

SONGS has not produced electricity since the plant shut down following a leak in a steam generator tube in 2012. The following year the plant officially closed. It is now in the process of being decommissioned.

The plant is located on an 85-acre chunk of Marine Corps Base Camp Pendleton, owned by the Department of the Navy. The plant sits between the Pacific and one of the busiest freeways in the country — Interstate 5. About 8.4 million people live within a 50-mile radius of the plant in an area with a history of seismic activity.

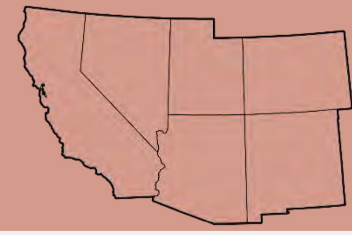
Distributed by Tribune Content Agency

Read or Share this story: https://www.vcstar.com/story/news/2019/03/26/edison-fined-its-handling-nuke-canisters/3282730002/

US Department of Energy Climate Change and the US Energy Sector-Regional Vulnerabilities and Resilience Solutions Excerpts (pp. 3-1 to 3-20)

Chapter 3: **Southwest**

Climate Change and the Energy Sector



Overview

The large and geographically diverse Southwest region includes mild coastal climates, an arid interior, and mountain ranges that store critical water supplies as snow. The region is home to a large and growing population. Key energy infrastructure includes oil and gas refineries and large amounts of power plant capacity. Major climate change impacts projected to increasingly threaten the region's energy infrastructure include the following:

- **Average temperatures and cooling degree days (CDDs) are projected to increase across the region, with hotter, more frequent, and longer-lasting heat waves.**[a] Increases in CDDs, extreme temperatures, and heat waves result in expanded air conditioner use. These projections are also expected to increase both average and peak demand for cooling while reducing the efficiency and available capacity of power plants and transmission lines.[b]
- **Average and summer seasonal precipitation is projected to decrease, droughts are projected to intensify, and streamflow in major river basins is projected to decline.**[c] Power plants that rely on surface water for cooling may face shortages and ecological or safety-related curtailments that reduce available generation capacity. Oil producers may also face water shortages.[d]
- **Spring thaws are projected to occur earlier, and a greater fraction of precipitation is projected to fall as rain rather than as snow, reducing mountain snowpack.**[e] Alongside reduced overall precipitation, less snowpack could reduce total potential hydropower production at high-elevation dams. Changing streamflow timing, decreased precipitation, and increased evaporation may impair hydropower production during peak summer electricity demand.[f]
- **The risk of wildfire and the annual average area burned is expected to increase across the region.**[g] Wildfires threaten physical damage to power lines, including fouling of lines and increased risk of arcing.[h]

QUICK FACTS

Southwest States:	Arizona, California, Colorado, Nevada, New Mexico, Utah
Population (2013)	58,000,000 (18% of U.S.)
Area (square miles)	686,000 (19% of U.S.)
Energy expenditures	$208 billion

ENERGY SUPPLY & DEMAND		Annual Production	Annual Consumption	*% for electric power*
Electric power	*TWh*	474	476	*n/a*
Petroleum	*MMbbls*	362	948	*<1%*
Coal	*million tons*	76	75	*96%*
Natural gas	*Bcf*	3,662	3,920	*38%*

ELECTRIC POWER	Annual Production (TWh)	*% of Total Production*	Capacity (GW)	Power plants >1 MW*
Natural gas	202	*44%*	84	398
Coal	136	*30%*	24	42
Nuclear	50	*11%*	9	3
Hydroelectric	38	*8%*	19	347
Wind	19	*4%*	9	147
Geothermal	15	*3%*	3	57
Biomass	7	*1%*	2	119
Solar	3	*<1%*	2	214

CRITICAL INFRASTRUCTURE			
Petroleum		**Electric Power**	
Wells (>1 boe/d):	64,400	Power plants (> 1 MW):	1,346
Refineries:	29	Interstate transmission lines:	32
Liquids pipelines:	21	**Coal**	
Ports (>200 tons/yr):	6	Mines:	26
Natural Gas		**Waterways**	
Wells:	68,500	Coal and petroleum routes:	5
Interstate pipelines:	30	**Railroads**	
Market hubs:	5	Miles of freight track:	14,000

Note: Table presents 2012 data except number of oil wells, which is 2009 data.
*Some plants use multiple fuels, and individual generating units may be <1 MW.
Sources: AAR 2014, EIA 2011a, EIA 2013a, EIA 2013b, EIA 2013d, EIA 2014a, EIA 2014b, EIA 2014c, EIA 2014e, EIA 2014h, EIA 2014i, EIA 2014k, US Census Bureau 2014, USACE 2014

Table 3-1. Examples of important energy sector vulnerabilities and climate resilience solutions in the Southwest

Subsector	Vulnerability	Magnitude	Illustrative Resilience Solutions
Electricity Demand	Increased demand for cooling energy from increasing CDDs and average and peak temperatures[i]	Increases of up to 1,000 CDDs by mid-century, with peak demand increasing 12%–24% owing to higher extreme temperatures[j]	Capacity expansion, increased power imports, efficiency, and demand-side management
Thermoelectric Power Generation	Reduced power plant capacity due to higher temperatures and reduced water availability, and coastal plants vulnerable to sea level rise[k]	Capacity reductions of up to 4.5%, up to 12 coal-fired power plants vulnerable to water shortages, and 25 coastal plants vulnerable to sea level rise[l]	Capacity expansion and diversification, water-efficient technologies, coastal hardening
Hydropower Generation	Reduced capacity in some seasons from earlier peak streamflow, and declining snowpack and precipitation[m]	Snowpack reductions of up to 43% in California by the end of the century[n]	Integrated water planning to optimize water use, upgraded equipment to increase efficiency
Electric Grid	Reduced capacity from higher temperatures, and threat of disruptions from increased wildfires[o]	Transmission line capacity losses of 1.5%–2.5%, substation losses of 1%–3% from rising temperatures[p]	Transmission capacity expansion and redundancy, improved vegetation management

Regional Energy Sector Vulnerabilities and Resilience Solutions

The following sections discuss key energy subsectors and illustrative examples of resilience solutions in the Southwest. System components that are most vulnerable to climate change are described first.

Electricity Demand

Subsector Vulnerabilities

Electric power demand in the Southwest is dominated by end-use in California, accounting for more than half of the region's electricity consumption (EIA 2013c).[1] Interregional electricity flows are oriented towards serving California's load. In the Western Interconnection (shown Figure 3-1), hydropower resources in the Northwest and mixed generation in the interior Southwest supply almost 25% of California's electricity (EIA 2011b). Power imports from the Northwest peak during spring and early summer (DOE 2012, EIA 2011b, EIA 2014d). Arizona, New Mexico, and Utah are net power exporters, producing 48%, 58%, and 33% more power than they consume, respectively (EIA 2013c).

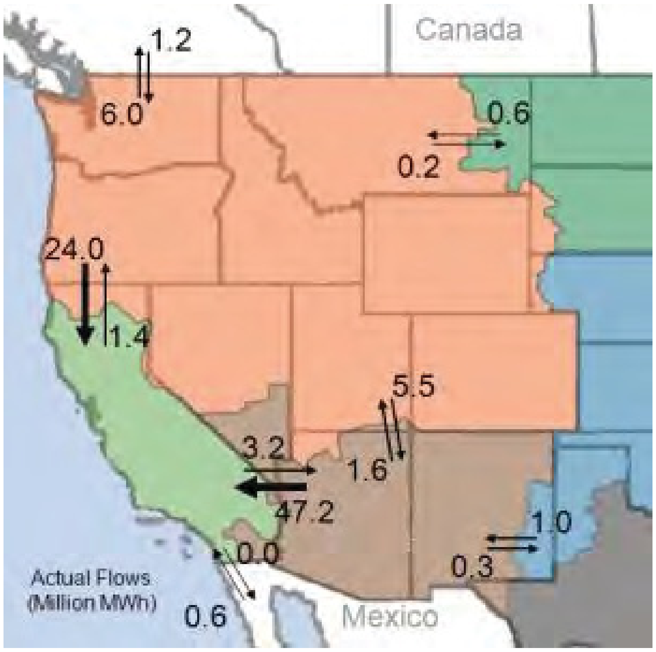


Figure 3-1. Annualized net electricity flows within the Western Interconnection in 2010 (Million MWh)

Source: EIA 2011b

[1] On a per capita basis, California's electricity consumption is about 40% lower than other states in the region (EIA 2013c). This is partly due to the relatively low number of CDDs experienced in California's coastal cities, as well as the lower rate of air conditioning use in California households. In California, 56% of households are air conditioned, while the average rate is 71% for other states in the region and 91% in Arizona, the region's second most populous state (EIA 2013c, EIA 2013g).

Climate change is expected to affect the region's electricity demand in the following ways:

- Higher average temperatures will increase the number of CDDs, increasing demand for cooling energy (NOAA 2013, USGCRP 2014).
- Hotter summer temperatures and an increase in the length, intensity, and frequency of heat waves are expected to increase peak electricity demand, potentially exceeding current generation and transmission capacities in some areas (NOAA 2013, Sathaye et al. 2012, USGCRP 2014).

Changes to temperature and to the total annual number of CDDs are expected to be largest where temperatures are already highest. For example, southeastern California and southwestern Arizona could see an increase of up to 1,000 CDDs per year (Figure 3-2). Important changes in electricity demand may also occur where populations are concentrated and the percentage of homes currently with air conditioners is low, such as coastal California. In these areas, large scale adoption of air conditioners may result in significant increases in electricity demand (EIA 2013g, NOAA 2013).

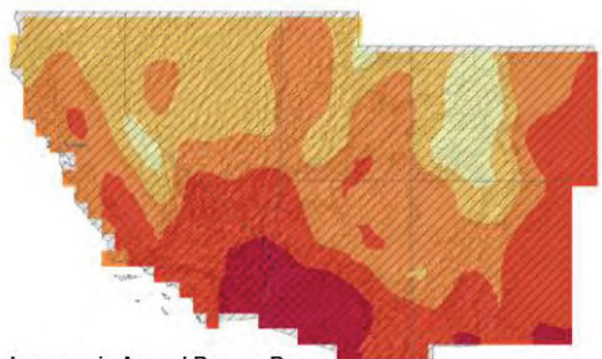


Figure 3-2. Increase in annual CDDs by mid-century under an A2 emissions scenario

Source: NOAA 2013

Under a higher emissions scenario, higher temperatures alone could increase average per capita peak energy demand in California by 12%–24% by the end of the century (compared to 2003–2009), according to an analysis conducted by the California Energy Commission (CEC) (Sathaye et al. 2012). This study supports the findings of an earlier CEC study that estimated end-of-century increases in peak demand due to temperature increases alone could be 4%–19% (compared to 1961–1990), depending on emissions scenario (Miller et al. 2007). When population and economic growth are considered, increases in peak electricity demand could be even larger, as regional population is projected to increase 68% by 2050 (DOE 2015a). Almost half of California households do not currently have air conditioning; cooling energy demand may grow at a faster rate than increases in CDDs if efficiency improvements do not offset additional air conditioning penetration (Auffhammer 2011, EIA 2013c). In states with already-high air conditioning use, such as Arizona and Nevada, increases in demand for cooling energy may increase faster than the rise in average temperatures (Aroonruengsawat and Auffhammer 2009).

The effects of extreme temperatures on electricity demand will be exacerbated by the influence of urban heat islands since air conditioning use is focused in urbanized areas. The three most extreme urban heat islands in the previous decade, as measured by the temperature difference between urban centers and surrounding areas, are located in the region: Albuquerque, Denver, and Las Vegas (Figure 3-3) (Climate Central 2014b).

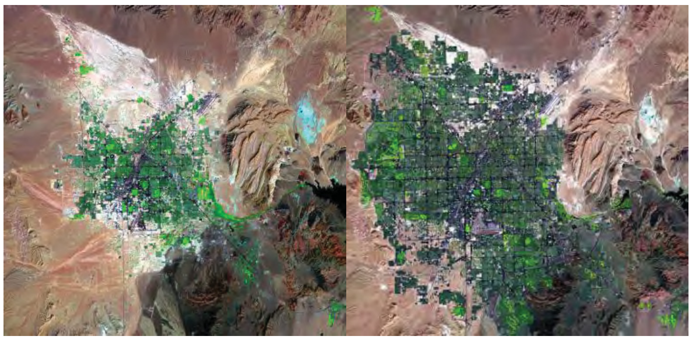


Figure 3-3. Satellite images showing population growth in Las Vegas, Nevada, from 1982 (left) to 2013 (right), which contributes to increasing electricity and water demand
Source: USGS 2015

The seasonal timing of peak energy demand and the potential for reduced availability of power imports from the Northwest may compound the effects of increased energy demand from temperature alone. California relies heavily on power imports from the Northwest during the summer (EIA 2011b). The Northwest, which generates more than 70% of its power from hydroelectric plants, is projected to experience shifts in the timing of snowmelt and peak streamflows away from the summer and towards the early spring, potentially making less power available to export to the Southwest region in the summer (USGCRP 2014).

In the winter, the region is expected to experience a decrease in the number of heating degree days, reducing the demand for heating energy (USGCRP 2014). Heating energy is provided by electricity and other fuels, such as natural gas. Southwest states with cold winters, including Colorado, use primarily natural gas as a space heating fuel; while states with mild winters, including Arizona, use mainly electricity for space heating (EIA 2013g). On average, electric utilities in the region have a summer demand peak about 25% higher than their winter peak, and warmer temperatures in the Southwest are likely to increase the summer electricity peak more than they will decrease the winter electricity peak (ANL 2008, EIA 2013h).

Electricity Demand

Resilience Solutions

Strategies to address increasing electricity demand include capacity expansion, energy efficiency, and implementation of measures that reduce demand at peak hours. New generating capacity can be designed to operate year-round (baseload) or only during periods of greatest demand (peaking). Demand can be reduced through improved end-use energy efficiency and demand management strategies.

Because of economic and population growth trends, new technologies such as electric vehicles, as well as climate change-driven reductions in existing generation capacity, new capacity may be a necessary part of a comprehensive response strategy to increases in peak demand. Evolving emissions regulations and existing water constraints suggest that new baseload thermoelectric plants in the region may employ water-efficient combined-cycle natural gas turbines similar to the Public Service Company of New Mexico's (PNM's) Afton plant, which uses hybrid cooling technology (PNM 2011). A study of demand growth and capacity changes found that gas-fired peaking generators may be required to meet peak electricity demand (Sathaye et al. 2012). New solar power can also contribute to meeting growing peak demand.

Efficiency standards reduce total energy demand, and most states in the region have integrated energy efficiency into statewide electric sector planning and regulations (ACEEE 2014a). In the past decade, Arizona, California, Colorado, and New Mexico state legislatures have all passed new energy efficiency resource standards (EERS) with quantitative targets for investor-owned utilities requiring that they achieve consumption reduction goals. In addition, both California and New Mexico have policies in place that decouple utility profits from the amount of electricity sold to customers (ACEEE 2014a). In 2008, California adopted a strategic plan for energy efficiency that ensures that energy efficiency is the highest priority resource for meeting current and future energy demand (CPUC 2008). CEC also approved new building codes that exceed International Energy Conservation Code (IECC) standards by 25% for residential buildings and 30% for nonresidential construction (CEC 2014a). Many regional utilities offer rebates for energy efficiency measures. For example, Colorado Springs Utilities offers rebates to residential customers of up to $250 each for upgraded windows, appliances, and other improvements (CSU 2014). In response to energy savings goals set by the Public Utilities Commission of the State of Colorado in 2008, the state's largest investor-owned utility, Xcel Energy, has spent almost $320 million on energy efficiency incentives through 2013 (SWEEP 2014). Similarly, Pacific Gas and Electric Company (PG&E) has an energy efficiency program that covers a diverse array of programs and services, some of which helped customers save more than $155 million in 2013 (PG&E 2014a).

Salt Lake City actions for greater climate resilience

Salt Lake City, Utah, which has been recognized as a Climate Action Champion by the White House, is working to improve resilience in part by reducing its energy consumption (White House 2015). As outlined in *Sustainable Salt Lake–Plan 2015*, goals for 2015 include reducing city-wide building energy use by 5%, increasing the number of LEED and EnergyStar buildings, and converting all city facilities to “net-zero” energy use (SLC 2014).

Demand response is another method for reducing peak demand. California’s demand response resource represents slightly more than 5% of California’s 2012 peak load (FERC 2013). In addition, the California Public Utilities Commission, CEC, and the state’s independent system operator (CAISO) have been working to allow residential ratepayers to participate in demand response, potentially expanding the resource (FERC 2013). Arizona Public Service (APS) offers a cooling energy load management program with financial incentives that allows APS to control customer thermostats to reduce air conditioning load during summer peak demand periods (DOE 2014b). Similarly, Las Vegas utility NV Energy offers commercial customers rate incentives for use of remotely controllable thermostats that reduce cooling during peak demand periods. Tucson Electric Power offers its commercial, institutional, and industrial customers a year-round program that compensates participants for reducing electricity usage during peak demand events (DOE 2014b).

Thermoelectric Power Generation

Subsector Vulnerabilities

Power in the Southwest is generated from diverse sources; natural gas, coal, nuclear, biomass, and geothermal power plants produced 87% of the region’s net electric generation in 2012 (EIA 2013c). The efficiency of thermoelectric power plants is sensitive to ambient air and water temperatures, and the plants need large amounts of water to generate steam and to cool process components. The Southwest is predominantly arid, and much of the region has traditionally experienced water constraints. For this reason, few thermoelectric plants in the region use freshwater-intensive once-through cooling systems and instead employ recirculating cooling and, increasingly, advanced technologies such as wet–dry hybrid and dry cooling (UCS 2012). Climate change is projected to further reduce water availability in some seasons and parts of the region, and increasing temperatures may exacerbate the impacts of water scarcity by reducing the efficiency of power production and increasing the volume of water required for cooling. Additionally, many thermoelectric plants along the coast that use seawater for cooling are vulnerable to the threats posed by accelerating sea level rise.

Climate change is projected to have the following impacts on thermoelectric power generation in the Southwest:

- Increasing average temperatures and more frequent and severe extreme temperatures are expected to reduce the efficiency and available generating capacity of thermoelectric power plants (DOE 2013, Sathaye et al. 2012, USGCRP 2014).
- Reduced availability of surface water resources and changing seasonal flow patterns of some sources of cooling water may increase the risk of thermoelectric power plant de-ratings (Cayan et al. 2013, DOE 2013, USGCRP 2014).
- Accelerating sea level rise increases the vulnerability of coastal energy infrastructure to inundation (Climate Central 2014a, NRC 2012, USGCRP 2014).

As temperatures increase, efficiency of thermoelectric power plants will decrease and, in turn, reduce available capacity. Plant equipment is typically designed for optimal operation at a set ambient temperature; deviation from those conditions can affect both efficiency and available capacity. The standard design conditions for air-breathing combustion turbines are 59° F (15°C) at pressure at sea level , and a 1°C increase in ambient temperature above the design point could reduce capacity by 0.7% for a combined-cycle gas plant and 1% for a simple cycle plant (Sathaye et al. 2012). Based on these rates, climate change-driven temperature increases could lead to reductions of 1.7%–4.5% of peak capacity across California's natural gas power plants by the end of the century (2070–2099), depending on emissions scenario (Sathaye et al. 2012).

Electric impedance in assets also increases with higher temperature, which leads to higher electric losses, and hotter processes require more cooling water to operate, meaning more power is required to pump greater volumes of water (DOE 2013). Higher air temperature also leads to warmer water temperature, which exacerbates the need for pumping. In some cases, hotter sources of cooling water can lead to mandatory plant shutdowns for environmental reasons (DOE 2013).

Only about half of the installed generating capacity in the region uses water-intensive once-through cooling, and of the plants that do, very few use freshwater sources (Figure 3-4) (UCS 2012). Most thermoelectric plants use recirculating cooling or use ocean water for cooling, and many of those that use freshwater for once-through cooling are set to retire or are inactive. Groundwater is a significant water source, although 74% of groundwater withdrawals for thermoelectric cooling are saline and do not currently compete with fresh groundwater users (UCS 2012, USGS 2005).

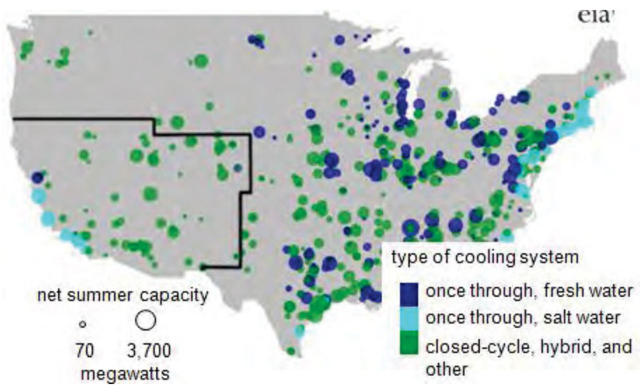


Figure 3-4. Types of cooling systems for U.S. plants (note limited once-through cooling systems that use freshwater sources in the Southwest)
Source: EIA 2012

Coal power plants in the interior may be particularly vulnerable to declining water supplies. One 2010 study found that, without taking future climate change into account, the water sources for 12 coal-fired power plants in the Southwest's Great Basin and Colorado River watersheds are already vulnerable to decreasing supply or increasing demand (Figure 3-5). Several of these plants have since reduced generation or closed (NETL 2010, PNM 2011).

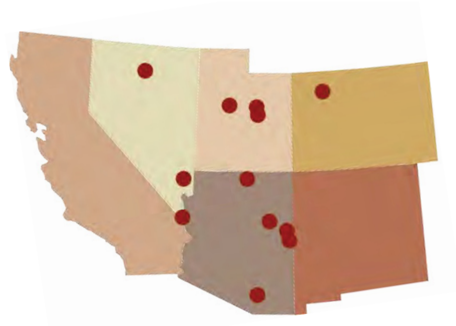


Figure 3-5. Coal power plants identified as vulnerable to water supply and demand concerns
Sources: EIA 2014c, NETL 2010

Coal-fired power plants are facing increasing economic pressure and may be retired before their lifetimes expire because of higher coal prices, lower wholesale electricity prices, increasing deployment of natural gas and renewable capacity, and environmental regulations that require investment in emissions reduction (EIA 2014l) (see side bar: The changing face of Southwest coal). For example, following passage of Colorado's Clean Air, Clean Jobs Act, which requires that utilities reduce emissions by 30% by 2020, Xcel Energy announced that 702 MW of coal-fired generation would be retired and replaced with new natural gas-fired generation (Xcel Energy 2015). Retirements of coal-fired generation may reduce the burden on the water supply. One study that considered aggregate thermoelectric water demand in the region found that in the reference case, freshwater withdrawals are estimated to fall 30% by 2050 (Macknick et al. 2012).[2] These declines are primarily due to the retirement of older thermoelectric units and introduction of natural gas-fired combined-cycle plants, which require significantly less cooling water than existing coal and nuclear plants (DOE 2013, Macknick et al. 2012).

Consumption of freshwater for thermoelectric power generation is projected to decrease in the Lower Colorado Basin, though total region-wide water consumption for power generation is not projected to change significantly (Macknick et al. 2012).

The changing face of Southwest coal

During the last decade, a number of large coal power plants in the region shut down, reduced their output, or secured new sources of water to cope with developing regulations and changes to water supplies (PNM 2011).

2013: PNM announced the decommissioning of two of four coal-fired units at the San Juan Generating Station, replacing the capacity with new natural gas plants and uprated nuclear capacity (EIA 2013d). Also, in response to the U.S. Environmental Protection Agency's (EPA's) Regional Haze Program, three of the five coal-fired units at the APS Four Corners Power Plant closed (Randazzo 2013).

2005: The 1,580 MW Mohave Generating Station closed after Southern California Edison was unable to secure necessary water and coal contracts to fulfill its obligations under a consent decree with the EPA (Edwards 2009).

2002: In response to drought conditions, PNM sought additional water sources for its San Juan Generating Station and entered into shortage sharing agreements with local tribes and other water users in the region (PNM 2011).

Sea level rise poses a threat to low-lying coastal power plants in California. Rising sea levels accelerate erosion and can increase the risk of inundation during high tides and storm surges. Approximately 25 coastal power plants have been classified as at risk of inundation from a 100-year flood with a 1.4-meter sea level rise, although site-specific analyses are required in order to establish actual risk (Sathaye et al. 2012).

[2] Estimate does not account for increased demand due to climate change but does include economic and population growth as well as the retirement and replacement of older plants.

Thermoelectric Power Generation

Resilience Solutions

Strategies to increase power plant resilience include the addition of new capacity (including low-water renewables such as wind or solar photovoltaics [PV]), deployment of water-efficient technologies and non-traditional water sources for cooling, and coastal hardening for plants vulnerable to sea level rise.

Reduced available generation capacity is primarily addressed by building new capacity or by importing additional power. Capacity reductions can also be ameliorated by demand-side efficiency and demand response programs (discussed in the Electricity Demand section).

Declining water availability can be addressed through deployment of technologies that increase water efficiency, use non-traditional water sources, or provide alternative generation sources that inherently require less or no water. Many thermoelectric power plants in the region already use recirculating cooling technology, and almost all plants in the region that use once-through cooling are supplied by ocean water (Table 3-2) (UCS 2012). In 2010, California opted to phase out once-through systems in coastal power plants, which will reduce withdrawals and the impact of discharge on California estuaries (CEC 2014c). Under a previous CEC policy, new power plants in California are essentially prohibited from using freshwater for cooling (CEC 2003).

Table 3-2. Southwest thermoelectric capacity by type of cooling technology, 2005

Once-through cooling	**51.4%**
Ocean water	*50.3%*
Surface	*0.9%*
Municipal	*0.2%*
Recirculating/cooling pond	**42.9%**
Groundwater	*14.5%*
Surface	*13.7%*
Wastewater	*8.3%*
Municipal	*6.2%*
Unknown	*0.2%*
Dry cooling	**4.4%**
Unknown/other	**1.3%**

Source: UCS 2012

Some new plants in the region are being built to use extremely water-efficient hybrid wet–dry cooling technology, which allows the plant to use cooling water when it is available but, in case of a shortage, to operate on dry cooling or with advanced dry cooling technologies that use minimal water. PNM's Afton Generating Station is a natural gas combined-cycle (NGCC) plant that uses hybrid cooling to reduce water intensity by 60% compared to PNM's other NGCC plant (PNM 2011). Three of PG&E's natural gas-fired power plants rely on dry cooling systems that minimize water use and discharge. The Humboldt Bay Generating Station uses minimal amounts of water by implementing a closed-loop liquid coolant cooling system with air radiators (PG&E 2014a). Compared to a plant with a traditional once-through cooling system, PG&E's Gateway Generating Station's air-cooled condenser requires about 97% less water and discharges about 98% less wastewater, and PG&E's Colusa Generating Station has a zero liquid discharge system that recycles wastewater (PG&E 2014a).

However, plants with dry cooling systems are more susceptible to decreasing efficiency due to high temperatures than those with wet cooling systems (GAO 2014, Garfin et al. 2013). Plants with dry cooling systems can lose 0.5% of capacity for every 1°F increase in peak temperature, about twice the capacity lost in plants with wet cooling systems under the same conditions (Garfin et al. 2013, Gordon and Ojima 2015).

Switching to non-traditional water sources, such as saline groundwater, municipal and industrial wastewater, and recycled brown water from landscaping, also present viable options for resilient water supplies (PNM 2011). For example, the Palo Verde Nuclear Generating Station in Arizona has been converted to use municipal wastewater (Figure 3-6) (PNM 2011).

Figure 3-6. The Palo Verde Nuclear Generating Station, which uses municipal wastewater for cooling
Source: USNRC 2015

Expanded deployment of renewable technologies such as wind and solar PV could significantly reduce water demand for energy. In low-carbon scenarios with wider deployment of solar PV and wind technologies, 2050 water withdrawals and consumption could decline up to 90% and 72%, respectively, depending on technology assumptions (Macknick et al. 2012). To support clean renewables in the region, the U.S. Department of Energy (DOE) has granted a number of loan guarantees for solar PV and wind projects. For example, DOE issued a loan guarantee to support the 550 MW Desert Sunlight solar PV project in California, the nation's largest solar project on public lands. Deployment of solar PV projects near thermoelectric power plants can provide additional benefits by shading water supply for these plants, potentially reducing evaporation from the water supply and decreasing the temperature of the intake water.

DOE has also supported expanded deployment of solar thermal technologies that employ low-water strategies in the Southwest. One such project is the 392 MW Ivanpah Solar Generating Station in California (Figure 3-7). The plant employs advanced dry cooling technology for its steam condensers to reduce its burden on freshwater resources, and it uses groundwater to supplement evaporative losses as well as to wash its mirror array, while it also recycles on-site wastewater to further reduce water needs (CEC 2014b).

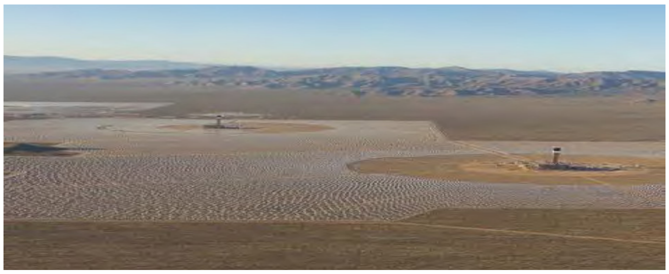


Figure 3-7. Ivanpah Solar Electric Generating System
Photo Credit: BrightSource Energy

Beyond technology changes, operations and planning can also improve resilience to water shortages. For example, the Public Utilities Commission of the State of Colorado requires that generators bidding to serve new power to investor-owned utilities must disclose information about the source and cost of their water supplies (WWA 2011). For coastal impacts from sea level rise and erosion, resilience solutions include hardening shorelines and sub-sea infrastructure (such as water intakes) to resist erosion and scouring, installing engineered barriers such as levees, raising vulnerable equipment, ensuring critical equipment is submersible, upgrading plants with watertight doors, and building coastal defenses like wetland habitats, where relevant.

Hydroelectric Power

Subsector Vulnerabilities

Hydropower is a significant resource in the Southwest, with approximately 19 GW of installed capacity providing 8% of electricity generation (EIA 2013c, EIA 2013d). More than 70% of the region's capacity is located in California, where most dams are powered by highly seasonal melting snowpack from the Sierra Nevada mountains (Figure 3-8). In addition to its own hydropower generation, California also relies on hydropower imports from the Northwest to meet its peak summer power demands.[3] The Colorado River watershed hosts a smaller number of large dams, including the Glen Canyon and Hoover dams (Figure 3-9).

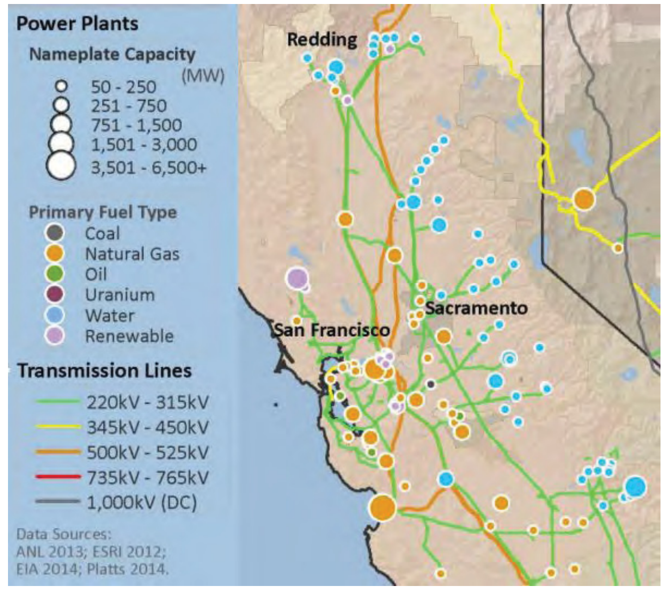


Figure 3-8. Hydroelectric facilities (blue) in the Sierra Nevada
Source: DOE 2015b

Figure 3-9. The 1,312 MW Glen Canyon Dam on the Colorado River watershed in Arizona
Source: USBR 2009

Hydropower production in the region is vulnerable to the following climate impacts:

- Declining April 1 snowpack and earlier spring snowmelt is expected to shift peak streamflow timing in snowmelt-fed rivers, potentially reducing summer water availability and hydropower generation (AEG and Cubed 2005, Cayan et al. 2013, NOAA 2013, USGCRP 2014).
- Winter precipitation is expected to increase, with a greater fraction expected to fall as rain rather than as snow. Overall, annual average precipitation is expected to decline (Barnett et al. 2008, NOAA 2013, USGCRP 2014).

[3] Northwest hydropower production and climate vulnerabilities are discussed in the Northwest regional profile.

Climate impacts affecting hydropower generation are expected to result from changes to both the total amount of water available in the region and to the timing of seasonal snowmelt and water flows. These changes could diminish the availability and capacity of hydropower resources.

From 2012 through 2014, California experienced historic drought conditions and a reduction of approximately 34,000 GWh of hydroelectricity compared to average water years. The cost of reduced hydroelectricity production and the use of additional natural gas to meet energy demand was estimated at $1.4 billion dollars (Pacific Institute 2015). The drought has continued in 2015, and is projected to contribute to a 10.4% decrease in annual hydropower in the United States in 2015 compared to 2014 (EIA 2015b).

Changes in regional precipitation and increasing evapotranspiration are generally expected to reduce water availability across the region. During the last decade, precipitation declines compared to the historical average in both the Sacramento–San Joaquin and Colorado River basins have been correlated to significant declines in streamflow (Garfin et al. 2013).[4] In the Colorado River watershed, reduced precipitation may exacerbate water management issues already being faced by the basin's major dams. One study estimates that without taking climate changes into account, there is already a 50% chance that the lakes could hold insufficient quantities of water to produce power by 2021 (Barnett and Pierce 2008).

Of California's fleet of dams, high-elevation dams are the most important for hydropower generation,[5] but they typically have much smaller reservoirs than low-lying dams and are more reliant on snowpack to supply water in the spring and early summer (AEG and Cubed 2005). For California's hydropower resources, changes to total annual precipitation may be less important than a number of factors affecting the accumulation and timing of winter snowpack, including increases in winter precipitation, shifts from snow to rain, and earlier spring snowpack melting.

Winter precipitation is projected to increase by mid-century (NOAA 2013). But as winters become warmer, more winter precipitation is expected to fall as rain rather than snow, decreasing snowpack (Barnett et al. 2008, USGCRP 2014). The trend toward increased winter rainfall is strongest in California's Sierra Nevada range, where most of California's high-elevation hydropower is located (EIA 2014c, Knowles et al. 2007). Furthermore, the annual pattern of spring snowpack melting is expected to occur earlier across the region as winter and spring temperatures increase (USGCRP 2014). Earlier peak melting presents problems for power planning since greater hydropower production is desirable during the summer when electricity demand is the highest. The total amount of snowpack available on April 1 has fallen at measurement sites across much of the region since 1955.[6] In 2015, April 1 snowpack was 6% of the long-term average, the lowest water content on record, owing to high temperatures and dry conditions that a recent study suggests are more likely to co-occur in the future (CDWR 2015, Diffenbaugh et al. 2015). Climate change is expected to lead to significant continued reductions in snowpack (EPA 2014, USGCRP 2014). Under a higher emissions scenario (A2), California snowpack could fall to 43% of recent levels by the end of this century (2070–2099) compared to 1971–2000 (USGCRP 2014).

It is uncertain how these changes will interact to affect the total accumulation of high-elevation snowpack, and thus the region's ability to produce hydropower, but the effects could be substantial. One study estimates annual streamflow changes could drive changes in generation in California's American River Watershed ranging from a 13% decrease to a 14% increase by 2070–2099, depending on emissions scenario and other modeling uncertainties (Vicuna et al. 2007).[7]

Hydroelectric Power

Resilience Solutions

Operational measures to increase hydropower resilience will require consideration of a larger integrated water management approach, as seasonal and extended water scarcity continues to have an impact on the region. In the face of competing demands, and depending on available alternatives, hydropower may not be seen as the highest-priority user. Reducing spill and better utilizing or storing early-spring runoff can improve hydropower resilience but may conflict with other water management goals, such as flood control. Expanding and diversifying non-hydro capacity would help ensure reliable electricity delivery during dry periods.

---

[4] During the last decade (2001–2010), streamflow in the Sacramento–San Joaquin basin was 37% lower and precipitation 7% lower than average amounts for the period 1931–2000. On the Colorado River, streamflow was 16% lower and precipitation 4% lower than the average levels for 1901–2000.

[5] The primary purpose of many low-elevation dams in California is flood control and water supply, not power production (AEG and Cubed 2005).

[6] In the southern Sierra Nevadas, the recent historical trend has not followed the regional pattern of earlier melting, as wetter-than-average conditions have acted to increase April 1 snowpack (EPA 2014, Pierce et al. 2008). Long-run warming is expected to reverse this trend and lead to declines in snowpack in the southern range (Cayan et al. 2013, USGCRP 2014).

[7] The study examined the 11 reservoirs and 8 hydroelectric facilities that compose the Sacramento Municipal Utility District's Upper American River Project and modeled system impacts under the A2 and B1 climate change scenarios.

PG&E has actively engaged with state and local stakeholders and developed strategies to adapt to reductions in snowpack in the Sierra Nevada Mountains. These strategies include maintaining higher winter carryover reservoir storage levels, reducing discretionary reservoir releases, and developing new modeling tools for forecasting runoff (GAO 2014, PG&E 2014a).

For dams facing declining water availability, technological options to increase resilience include overhauling and upgrading plant equipment to minimize water leaks and increase turbine efficiency. In 2001, in response to falling water levels in Lake Mead, ongoing work by the Bureau of Reclamation to overhaul the Hoover Dam's 17 turbine-generator pairs shifted focus to increasing efficiency and regaining lost capacity. By reducing water leaks and overhauling the turbines, efficiency is now 3%–4% higher at each overhauled unit, and more water is being conserved for power generation (HydroWorld 2009). On a much smaller scale, the City of Boulder replaced the nearly 50-year-old turbine and generator at its Boulder Canyon Generating Station with a significantly more efficient 5 MW unit, increasing capacity by 30% (City of Boulder 2014).

To reduce the impact of decreasing hydropower production in dry years on customers, Sacramento Municipal Utility District (SMUD) has implemented a rate-stabilization fund, which uses savings from high-production years to buy power during drought years (Kasler 2014).

Electric Grid

Subsector Vulnerabilities

The operational structure of the electric grid varies within the Southwest region. In California, the grid is operated by CAISO, while interior states mainly have vertically integrated utilities that plan and operate generation and transmission capacity internally (DOE 2014a). In some parts of the Southwest, including parts of Arizona and New Mexico, there is less redundancy built into the grid system compared to other parts of the country (BLM 2013).

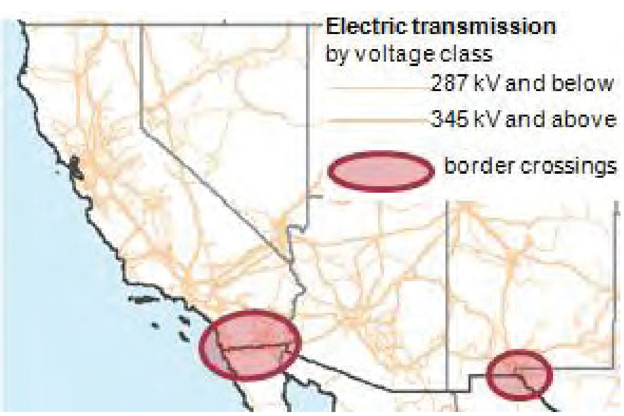


Figure 3-10. Power flows between the Southwest and Mexico, including a synchronous tie between California and Mexico
Source: EIA 2013i

small amount of power flows internationally between Mexico and California (EIA 2013i). The Comisión Federal de Electricidad (CFE) Baja California Control Area is connected by two 230 kV transmission lines to the Western Interconnection (Figure 3-10) (CEC 2008). The CFE Baja Control Area transmits power generated at two plants in Mexico with a combined capacity of 1,120 MW to supply demand in the San Diego area (CEC 2008). The tie in Baja California is the only synchronous cross-border tie between Mexico and the United States (EIA 2013i).

Interstate power flows in the region are generally oriented toward California (discussed in the Electricity Demand section). Several major power corridors, including the Pacific DC Intertie, the California–Oregon Intertie (Path 66), and the Intermountain Power Project DC line, supply significant peaking capacity to California from neighboring states (CAISO 2012). Across the region, construction of new transmission lines has accelerated in recent years, as electricity flows need to keep up with changing demand and distribution of existing generation, including upcoming retirements and new generating capacity (DOE 2014a).

Climate change could have the following impacts on the electric grid:

- Increasing frequency and size of wildfires and associated heat, soot, and application of fire retardants may damage and disrupt power transmission infrastructure (DOE 2013, Sathaye et al. 2012, USGCRP 2014).
- Increasing average and extreme temperatures reduce the capacity of power lines and substations and increase the risk of damage to power transformers (Bérubé et al. 2007, DOE 2013, Sathaye et al. 2012, USGCRP 2014).
- Rising sea levels increase the exposure of low-lying coastal substations to inundation during storm surges (Sathaye et al. 2012, USGCRP 2014).

Projected increases in the frequency and extent of wildfires heighten the risk of grid outages and safety shutdowns. Both tree mortality and wildfires have increased dramatically in the past several decades, with the area burned in western mid-elevation conifer forests increasing almost sevenfold during the late 20th century (USGCRP 2014).[8] Wildfires can burn and destroy wooden power poles that typically hold smaller transmission lines, and the associated smoke, soot, fire retardants, and heat from fires can damage and disrupt larger grid assets by fouling lines and insulators, increasing risk of arcing and reducing transmission capacity (DOE 2013, Sathaye et al. 2012, SDG&E 2008). For example, in early September 2015, the Valley, Butte, and Rough Fires damaged grid infrastructure

[8] The measurement period is 1970–2003.

Wildfire disrupts electricity in San Diego

In 2007, wildfire knocked out the Southwest Power Link, a transmission line connecting San Diego to distant generation, requiring 500 MW of load shedding in San Diego by San Diego Gas & Electric and Southern California Edison. Over the next week, fires took out two dozen additional transmission lines, destroying 35 miles of wire and 1,500 poles. Nearly 80,000 customers in San Diego lost power, some for more than two weeks (PPIC 2008, SDG&E 2007).

Figure 3-11. The Witch Creek/Guejito wildland urban interface fire of October 2007
Source: U.S. Department of Commerce 2013

and knocked out power to more than 15,000 PG&E customers in Northern and Central California (DOE 2015d).

Wildfire models have estimated the impact that climate change, in concert with other changes such as future development, may have on the extent of wildfires in the Southwest. In the southern Rockies, the average area burned each year may double by mid-century (Litschert et al. 2012, USGCRP 2014).[9] In California, projections indicate that under a higher emissions scenario, wildfires could increase in all forested areas by the end of the century (Sathaye et al. 2012). In the Sierra Nevada, fires are projected to increase by almost 75% by the end of the century (compared to 1960–1990) (USGCRP 2014).

Models estimating the probability of wildfire impacts on transmission lines in California have shown that lines in two regions—the state's northern border and the region north of Los Angeles—are particularly vulnerable to wildfire under higher emissions scenarios (Sathaye et al. 2012). Compounding the vulnerability of northern California is the lack of alternate or redundant routes to the Northwest power market and the projection that Path 66—the artery that connects northern California loads to low-cost Northwest hydropower and the Diablo Canyon nuclear plant—will become significantly more vulnerable to wildfire (Sathaye et al. 2012). Southern California relies on even greater amounts of power imports to meet peak demand in the summer, although with a larger number of transmission corridors; about one-third of peak capacity is provided via transmission lines connecting to interior states (Sathaye et al. 2012).

Higher temperatures may result in decreases in the available current-carrying capacity of power lines and substations and exacerbate vulnerabilities of the broader energy system in the region, particularly during peak demand periods (Figure 3-12) (DOE 2013). High temperatures cause thermal expansion of power line materials, and greater sag in transmission lines increases the risk of widespread power outages when lines arc to trees, the ground, or other power lines (DOE 2013). Furthermore, when transmission lines arc, they may ignite overgrown vegetation. To prevent damage to lines, operators may reduce the capacity on transmission lines. By the end of the century the combined effects of higher demand and temperature could increase total loss factors for the transmission and distribution grids by 1.5%–2.5%,

Impacts of higher electricity demand are compounded by efficiency reductions in power sector

A CEC study found that increasing energy demand and capacity losses across power sector infrastructure could, under a higher emissions scenario, require a 38.5% increase in the nameplate capacity of gas-fired peaking generators by the end of the century (Sathaye et al. 2012). Figure 3-12 shows how efficiency penalties along generation, transmission, and substations serve to compound the impacts of increasing energy demand on system resource requirements.

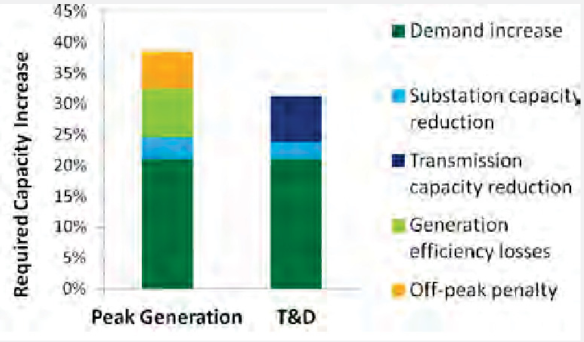


Figure 3-12. Required increase in capacity in California due to higher temperatures, in order to provide 1961–1990 levels of per-capita peak power by the end of this century. Assumes A2 scenario, and a 90th-percentile temperature.
Source: Based on Sathaye et al. 2012

[9] Increases are for the period 2041–2070, compared to 1970–2006.

while reducing capacity by 7%–8% (for a 9°F increase in air temperature) (Sathaye et al. 2012). Higher temperatures may also reduce substation capacity 1%–3% compared to current capacity (Sathaye et al. 2012).

Increased temperatures also shorten the lifetimes of power transformers. At higher temperatures, the insulation in transformers breaks down at an accelerated rate (Bérubé 2007). At extreme temperatures, such as those encountered during grid emergencies when some transformers may be overloaded, significant overheating can rapidly shorten transformer lifetime. On very hot days, grid operators must reduce transformer loading or risk causing additional damage (Hashmi et al. 2013, USBR 2000). Increasing nighttime temperatures will prevent equipment from cooling off, which may exacerbate the effects of high temperatures on power lines and transformers (DOE 2013).

As climate change leads to higher relative sea levels, coastal flooding may pose a risk to some low-lying electric substations, especially when combined with storm surge. In a scenario with a 4.6-foot rise in sea level, one study determined that 3% of California's electric substations would be vulnerable to a 100-year coastal flood (Sathaye et al. 2012).[10] Increases in winter precipitation may also affect inland flooding via rain-on-snow events, which produce large amounts of runoff in mountain drainages. However, recent trends in the Western United States have shown these events occurring less frequently (McCabe et al. 2007, USGCRP 2014).

Electric Grid

Resilience Solutions

Measures to improve the resilience of new and existing electric transmission infrastructure include engineering structures to better withstand sea-level rise and hotter conditions, increased fire management practices to reduce short-term threats such as overloaded equipment, long-term planning to increase network redundancy where wildfires are likely to occur, and transmission capacity expansion when necessary (DOE 2013).

To reduce wildfire risk, utilities engage in vegetation management, including tree trimming, as well as thinning and prescribed burning to reduce fuel buildup (USGCRP 2014). Adequate vegetation management can also reduce the risk of wildfires caused by tree strikes, and California regulators have cleared the way for utilities to take more proactive measures by requiring management on lower-voltage power lines and by allowing utilities to cut off service to properties that will not allow tree trimming (EEI 2014). Three California utilities—San Diego Gas & Electric (SDG&E), PG&E, and Southern California Edison—are also jointly funding the development of a statewide fire-threat map that will indicate physical and environmental conditions that are associated with higher risk of power line fires (EEI 2014). PG&E has also partnered with local fire safe councils to help fund fuel reduction and emergency response access projects, such as installing remote fire detection cameras on lookout towers in critical fire risk areas (PG&E 2014b). To help ensure that power outages are identified and restored quickly, advanced communications and control technologies, such as state-of-the-art automated switch technologies, can "self-heal" the grid (PG&E 2015).

Technologies to improve transformer resilience include installing or upgrading cooling fans or replacing transformers with more expensive, higher-temperature-rated units (Bérubé et al. 2007, USBR 2000). Management practices for protecting grid equipment, such as reducing loading on transformers during heat waves, can help prevent short-term damage (Hashmi et al. 2013). In 2014, Colorado Springs Utilities partnered with Landis+Gyr to install an advanced load management program to protect distribution system assets during peak power consumption by dynamically reducing loads. The utility is planning to deploy 1,900 smart thermostats and software applications to enable load shedding on specific feeder circuits to protect transformers and other distribution equipment, while maintaining reliable electric service (Landis+Gyr 2014).

Illustrative electric grid resilience solutions

Following the damaging wildfires of 2007, SDG&E implemented greater minimum clearances for vegetation and has explored using LiDAR to identify clearance issues (Fotland 2012). The utility has also hardened critical portions of its lines, including replacing wood poles with steel, replacing power conductors with stronger steel-core lines, increasing transmission line spacing, and installing advanced line closers to protect lines in case of emergency. In June 2012, SDG&E activated the Sunrise Powerlink transmission line connecting San Diego to the Imperial Valley to improve reliability during summer heat waves (SDG&E 2012). SDG&E also partnered with the U.S. Forest Service and University of California, Los Angeles, to develop the Santa Ana Wildfire Threat Index, a web-based tool available to the public that assesses the risk of wildfires during Santa Ana wind events (Rolinski et al. 2014).

[10] Out of 2,690 substations, 86 are at risk (Sathaye et al. 2012).

Oil and Gas Exploration and Production

Subsector Vulnerabilities

The Southwest's oil and gas infrastructure includes oil and gas wells, oil refineries, and natural gas processing facilities. About 13% of domestic oil production is in the region, mostly in California, but also in New Mexico, Colorado, and Utah (EIA 2014a). The region's refinery capacity is also concentrated in California, mostly along the coast, and locally produced oil is primarily refined and consumed in the region (EIA 2014f, EIA 2014g). About 14% of the nation's natural gas is produced in the region, with Colorado and New Mexico as the largest producers (EIA 2013f).

Climate change may have the following impacts on oil and gas exploration and production:

- Rising sea levels, when combined with land subsidence and storm surge, could accelerate erosion and inundate low-lying and coastal oil and gas infrastructure (DOE 2013, USGCRP 2014).
- Declining water availability, including increased risk of drought, may affect production and refining operations that require freshwater resources (DOE 2013, Tiedeman et al. 2014, USGCRP 2014).

Flooding and inundation risks associated with rising sea levels may affect facilities along the entire California coastline, although land subsidence and concentrations of energy assets localize the impact to a few areas. Over the last century, sea levels in California have increased 6.7–7.9 inches. South of Cape Mendocino, where tectonic shifts are causing land subsidence, sea levels are expected to increase another 1.4–5.5 feet by 2100, depending on emissions scenario and other uncertainties (NRC 2012).

The vulnerability of specific energy assets is sensitive to their elevation and proximity to coastlines. An analysis of flooding impacts on utilities in Los Angeles (including electric power, water, and fuel systems) found that assuming 1.4 meter (4.6 feet) of sea level rise, combined with a once-in-100-year flood, caused moderate damage to three of the city's oil refineries but affected none of the city's power plants or natural gas facilities (Grifman et al. 2013).

Energy production can also be affected by prolonged drought. California's oil production is mostly composed of older wells undergoing water-intensive secondary and tertiary enhanced recovery processes. For the period 1999–2012, the water intensity of the median California oil well increased more than 20%, and many wells are located in areas that may experience moderate to severe water stress by 2025 (Tiedeman et al. 2014). In the midst of a recent drought, California has passed new legislation mandating that oil drillers report the amount and source of water used in oil recovery (California Department of Conservation 2015, Carroll 2014). Throughout the region, hydraulically fractured wells, which require about 3–6 million gallons of water per well for drilling and fracturing (Mantell 2011), are located in areas with water stress challenges that could be exacerbated by declining precipitation. One study found that over 95% of hydraulic fractured wells in Colorado and California are in locations considered "high" or "extremely high" water stress (Ceres 2014).

Like thermoelectric power plants, oil refineries require a substantial amount of cooling water and may face escalating costs as droughts and critical water shortages become more frequent (DOE 2013).

Oil and Gas Exploration and Production

Resilience Solutions

Resilience strategies to protect the Southwest's coastal oil and gas infrastructure from inundation include both hardening and management solutions.

Oil and gas companies facing periodic water constraints on drilling and refining operations can use degraded water or wastewater to reduce demand for municipal or freshwater. For example, a BP oil refinery in Los Angeles recently switched to recycled municipal wastewater to meet some of its process water needs (Troeh 2012). Oil production operations using water-intensive enhanced oil recovery could expand use of brackish groundwater or reuse produced water (DOE 2013). Alternative fracturing techniques that are typically used to promote enhanced product recovery in select shale formations may also reduce water use; these includeLiquid Petroleum Gas (LPG) fracturing, which uses propane and chemical additives in lieu of water; foam-based fracturing, which uses water, a foaming agent, and nitrogen or carbon dioxide; and channel fracturing, which uses proppant-laden fluid and gelled fluid to create channels (GAO 2015). In addition, enhanced oil recovery using carbon dioxide injection from carbon capture, storage, and use activities could contribute to reduced greenhouse gas emissions (climate mitigation) as well as enhanced resilience to climate change. Because water management is already a high-priority issue for most Southwestern states, solutions to problems of increased energy infrastructure vulnerability will continue to require comprehensive resilience strategies that address stakeholders in multiple sectors.

Fuel Transport

Subsector Vulnerabilities

Much of the Southwest region is dependent on the extensive fuel transport infrastructure located along the California coast (Figure 3-13) (EIA 2014c). In particular, refineries in California rely on coastal infrastructure, such as ports in Los Angeles, Long Beach, and the Bay area, for imports of crude oil (EIA 2014c, CEC 2015). Once refined, gasoline and other petroleum products are transported primarily by pipelines to customers in California, Nevada, and Arizona (CDPC 2010). In addition, the region has become increasingly dependent on domestic shipments of crude oil by rail.

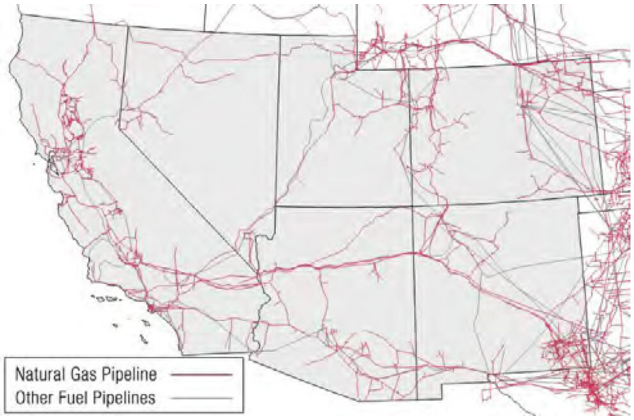


Figure 3-13. Natural gas and other fuel pipelines in the Southwest
Source: Adapted from EIA 2014c

New Mexico and Colorado are major producers of natural gas, which is consumed in-state and transported via pipeline to other western states. Markets in California are served by natural gas from Arizona, Nevada, and the Northwest (EIA 2014c). California exports and imports a limited amount of natural gas by pipeline to and from Mexico (EIA 2014m, EIA 2015a).

Climate change may have the following impacts on fuel transport:

- Rising sea levels could result in a higher rate of coastal erosion and a greater likelihood of flooding coastal infrastructure, including ports, terminals, pipelines, and railroads (CEC 2012, Sathaye et al. 2012, USGCRP 2014).

Coastal ports and facilities are vulnerable to increased flood regimes along the coast due to higher sea levels, and may be at greater risk of being forced to stop or delay operations during floods. According to one study, 80% of the Port of San Francisco, 60% of the Port of Oakland, and approximately 50% of the Port of Richmond in the Bay Area could be inundated during a 100-year flood event with 1.4 meters (4.6 feet) of sea level rise (CEC 2012). A 100-year flood event combined with sea level rise could also flood almost 1,700 miles of roadway in the Bay area, including almost 170 miles of major highways, stalling port operations by hindering the transport of personnel and goods (CEC 2012). Much of northern California's Sacramento–San Joaquin River Delta region has subsided below sea level and is already highly vulnerable to flooding. The delta contains significant natural gas infrastructure, including the McDonald Island natural gas storage facility and multiple pipelines, that supplies the Bay Area and Sacramento/Stockton (Sathaye et al. 2012).

Pipelines along the coast and in low-lying areas may be vulnerable to corrosion as coastal flooding associated with rising sea levels may increase saltwater intrusion of groundwater. As sea levels rise, pipelines may also be increasingly at risk from flooding that can expose buried pipe, making it susceptible to impact from flood-borne debris (DOE 2013). Pumping stations, terminals, low-lying railroad equipment and other fuel transport infrastructure near the coast are also at increased risk of damage from flooding and erosion as sea level rise accelerates.

Fuel Transport

Resilience Solutions

Fuel transport assets, including port facilities, can be hardened to mitigate the risks from sea level rise, reducing the likelihood of damaging coastal erosion and flooding events. For instance, sea walls and natural barriers such as wetlands can dampen the impacts of sea level rise and prevent coastal erosion in some instances. Pipelines may be upgraded to more robust materials such as coated steel or plastics to prevent corrosion and damage from flood-borne debris. Another resilience measure is elevating or relocating critical equipment such as pumping stations, port assets, and railroad structures out of coastal floodplains. For example, the McDonald Island natural gas storage facility is designed so that the compressor and wellhead controls can still operate under a 20 foot head of water (Sathaye et al. 2012). Some equipment can also be sealed in waterproof enclosures to prevent damage during flood events (DOE 2010). Planning for future sea level rise when siting and designing coastal transport infrastructure will improve long term resilience.

Regional Climate Change Observations and Projections in Detail

Higher Temperatures

Historical observations

- **Since 1895, temperatures have increased an average of 0.17°F per decade, or almost 2°F** (NOAA 2013).
- **Heat waves are occurring more often and cold waves less often:** For 1895–2011, there is a statistically significant increase in the number of heat waves across the region (NOAA 2013).

Future projections

- **Average temperatures are expected to increase at a faster rate, with summer and autumn increases most severe:** Under a higher emissions scenario (A2), temperatures are projected to increase 5.5°F–8.5°F by the end of the century (2070–2099, compared to the climate of 1971–1999), with the lowest increases along the coast. Under a lower emissions scenario (B1), increases may be 3.5°F–5.5°F (NOAA 2013).
- **Extremely hot days are projected to become more common, and consecutive number of days of extreme heat are expected to grow longer:** In the southern part of the region, especially in deserts, arid regions, and high plains, 25–40 more days with a daily maximum temperature >95°F are expected by mid-century (2041–2070, compared to 1980–2000), and the maximum number of consecutive hot days is projected to increase by 16–32; through most of the rest of the region, 10–25 more extremely hot days per year are projected, with annual maximum consecutive hot days growing by 4–16 (NOAA 2013).
- **Cooling degree days (CDDs) are expected to increase:** In much of the region, an increase of 400–1,000 CDDs is expected by mid-century (2041–2070, compared to 1980–2000); increases of 200–400 CDDs are expected in northern parts, and fewer in the Rockies (NOAA 2013).
- **Heating degree days (HDDs) are expected to decrease, cold nights to occur less frequently, and freeze-free season to grow:** The northern and mountainous parts of the region are expected to experience a decline in HDDs of 1,100–1,700 by mid-century (2041–2070, compared to 1980–2000); in the south and along the coast, declines of 500–1,100 HDDs are projected. The freeze-free season is expected to be 20–45 days longer by mid-century, and days with daily minimums less than 10°F are no longer expected to occur, except in high-elevation areas (NOAA 2013).

Changing Water Patterns and Wildfires

Historical observations

- **More winter precipitation has been falling as rain rather than as snow:** Across western mountain regions, October-to-March snow water equivalent (SWE), normalized by total precipitation, has fallen over the period 1950–1999, with a strong indication that up to 60% of the changes are due to climate change (Barnett et al. 2008).

Future projections

- **Annual mean precipitation is expected to decrease:** Under a higher emissions scenario (A2), end-of-century (2070–2099) precipitation is projected to be 3%–12% lower in the southern portion of the region than the period 1971–1999. Under a lower emissions scenario (B1), models are less certain (NOAA 2013).
- **Spring and summer are projected to be drier and winter wetter:** Spring and summer average precipitation may decline by more than 15% in parts of the region by mid-century (2041–2070, compared to 1971–2000); summer coastal precipitation is projected to increase more than 15%; winter precipitation is generally expected to increase, with regions seeing greater than 15% increases (NOAA 2013).
- **Periods with little or no precipitation are likely to become longer:** Across most of the region, the annual maximum number of consecutive days with less than three millimeters of precipitation is projected to increase 5–25 days per year by mid-century (2041–2070, compared to 1980–2000). Projected increases are smallest in eastern Colorado (NOAA 2013).
- **Snowpack may decline across the region:** By mid-century (2041–2070), April 1 SWE is projected to fall by more than 40% compared to 1971–2000 (Cayan et al. 2013).
- **Streamflow in many major basins is expected to decline:** By the 2070s, annual streamflow in the Klamath, Sacramento–San Joaquin, Colorado, and Rio Grande rivers is projected to decline relative to the 1990s (USGCRP 2014). For all but the Colorado River, declines are projected to be greatest between April and July (USGCRP 2014).
- **Droughts are expected to intensify across the region:** Future droughts in the region, and especially in the Colorado River watershed, are projected to become more frequent, intense, and longer-lasting than in the historical record (USGCRP 2014).
- **Risk of wildfire is expected to increase:** The area of land burned in wildfires is projected to increase, including a doubling of area in the southern Rockies by mid-century (2041–2070, compared to 1970–2006) and an almost 75% increase in northern California by end-of-century (compared to 1960–1990) (USGCRP 2014).

Sea Level Rise

Future projections

- **Sea level rise is expected to accelerate:** Along most of the California coastline (south of Mendocino), relative sea levels are projected to increase by 17–66 inches by 2100 compared to 2000, depending on emissions scenario and other uncertainties (NRC 2012).

Chapter 3 References

AAR (Association of American Railroads). 2014. "US Freight Railroad Industry Snapshot." Washington, DC: Association of American Railroads. http://www.aar.org/data-center/railroads-states.

ACEEE (American Council for an Energy-Efficient Economy). 2014a. "State Energy Efficiency Resource Standards." Washington, DC: American Council for an Energy-Efficient Economy. April. http://www.aceee.org/files/pdf/policy-brief/eers-04-2014.pdf.

ACEEE. 2014b. State and Local Energy Efficiency Policy Database. Accessed November 5. http://www.aceee.org/sector/state-policy.

AEG (Aspen Environmental Group) and M. Cubed. 2005. *Potential Changes in Hydropower Production from Global Climate Change in California and the Western United States*. Sacramento, CA: California Energy Commission. http://www.energy.ca.gov/2005publications/CEC-700-2005-010/CEC-700-2005-010.pdf.

ANL (Argonne National Laboratory). 2008. *Climate Change Impacts on the Electric Power System in the Western United States.* Thomas D. Veselka. Argonne, IL. http://www.dis.anl.gov/news/WECC_ClimateChange.html.

Aroonruengsawat, A., and M. Auffhammer. 2009. *Impacts of Climate Change on Residential Electricity Consumption: Evidence from Billing Data*. Sacramento, CA: California Energy Commission. March. http://www.energy.ca.gov/2009publications/CEC-500-2009-018/CEC-500-2009-018-D.pdf.

Auffhammer, M. 2011. *Report #3: The Relationship Between Air Conditioning Adoption and Temperature*. Washington, DC: U.S. Environmental Protection Agency. October. http://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0573-01.pdf/$file/EE-0573-01.pdf.

Barnett, T. P., and D. W. Pierce. 2008. "When will Lake Mead go dry?" *Water Resources Research* 44. W03201, doi:10.1029/2007WR006704. http://www.image.ucar.edu/idag/Papers/PapersIDAGsubtask2.4/Barnett1.pdf.

Barnett, T. P., D. W. Pierce, H. G. Hidalgo, C. Bonfils, B. D. Santer, T. Das, G. Bala, A. W. Wood, T. Nozawa, A. A. Mirin, D. R. Cayan, and M. D. Dettinger. 2008. "Human-induced changes in the hydrology of the Western United States." *Science* 319:1080–1083, doi:10.1073/pnas.0812762106. http://tenaya.ucsd.edu/~dettinge/barnett08.pdf.

Bérubé, J., J. Aubin, and W. McDermid. 2007. "Transformer winding hot spot temperature determination." *Electric Energy T&D Magazine*. March/April. 2 Vol. 11. http://www.electricenergyonline.com/show_article.php?article=311.

BLM (U.S. Bureau of Land Management). 2013. *Final Environmental Impact Statement and Proposed Resource Management Plan Amendments for the SunZia Southwest Transmission Project*. Washington, DC: U.S. Bureau of Land Management. June. http://www.blm.gov/pgdata/etc/medialib/blm/nm/programs/more/lands_and_realty/sunzia/sunzia_feis/feis_entire_doc.Par.94589.File.dat/00_SunZia_Southwest_Transmission_Project_FEIS_and_Proposed_RMP_Amendments.pdf.

CAISO (California Independent System Operator). 2012. *2012 Summer Loads and Resources Assessment*. Folsom, CA: California Independent System Operator. March. http://www.caiso.com/Documents/Briefing_SummerLoads_ResourcesOperationsPreparednessAssessment-Report-MAR2012.pdf.

California Department of Conservation. 2015. "Welcome to the Division of Oil, Gas & Geothermal Resources." Accessed March 19. http://www.conservation.ca.gov/dog/Pages/Index.aspx.

Carroll, R. 2014. "California Senate approves bill requiring oil industry to detail water use." *Reuters*. August 20. http://www.reuters.com/article/2014/08/29/us-usa-california-water-idUSKBN0GT04V20140829.

Cayan, D., M. Tyree, K. Kunkel, C. Castro, A. Gershunov, J. Barsugli, A. Ray, J. Overpeck, M. Anderson, J. Russell, B. Rajagopalan, I. Rangwala, and P. Duffy. 2013. "Ch. 6: Future climate: Projected average." In *Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment*. G. Garfin, A. Jardine, R. Merideth, M. Black, and S. LeRoy, eds. Washington, DC: Island Press, 153-196. http://swccar.org/sites/all/themes/files/SW-NCA-color-FINALweb.pdf.

Ceres. 2014.*Hydraulic Fracturing & Water Stress: Water Demand by the Numbers.* M. Freyman. Boston, MA: Ceres. February. http://www.ceres.org/resources/reports/hydraulic-fracturing-water-stress-water-demand-by-the-numbers.

City of Boulder. 2014. "Boulder Canyon Hydroelectric Plant Modernization Project." Accessed December 11. https://bouldercolorado.gov/water/boulder-canyon-hydroelectric-plant-modernization-project.

Climate Central. 2014a. "Energy infrastructure threat from sea level rise." Accessed September 19. http://sealevel.climatecentral.org/maps/energy-infrastructure-threat-from-sea-level-rise.

Climate Central. 2014b. "Hot and Getting Hotter: Heat Islands Cooking U.S. Cities." August 20. http://www.climatecentral.org/news/urban-heat-islands-threaten-u.s.-health-17919.

CDPC (California Delta Protection Commission). 2010. *Land Use and Resource Management Plan*. West Sacramento, CA: California Delta Protection Commission. http://www.delta.ca.gov/plan.htm.

CDWR (California Department of Water Resources). 2015. "Snow Water Equivalents (inches)." California Cooperative Snow Surveys, California Data Exchange Center. http://cdec.water.ca.gov/cdecapp/snowapp/sweq.action.

CEC (California Energy Commission). 2003. *2003 Integrated Energy Policy Report.* Sacramento, CA: California Energy Commission. December. http://www.energy.ca.gov/reports/100-03-019F.pdf.

CEC. 2008. *Current Status, Plans, and Constraints Related to Expansion of Natural Gas-Fired Power Plants, Pipelines, and Bulk Electric Transmission in the California/Mexico Border Region.* Sacramento, CA: California Energy Commission. August. http://energy.ca.gov/2008publications/CEC-600-2008-008/CEC-600-2008-008.pdf.

CEC. 2012. *Climate Change Impacts, Vulnerabilities, and Adaptation in the San Francisco Bay area: A Synthesis of PIER Program Reports and Other Relevant Research.* Sacramento, CA: California Energy Commission. July. http://www.energy.ca.gov/2012publications/CEC-500-2012-071/CEC-500-2012-071.pdf.

CEC. 2014a. "2013 Building Energy Efficiency Standards website." Accessed November 18. http://www.energy.ca.gov/title24/2013standards/.

CEC. 2014b. "Ivanpah Solar Electric Generating System." Accessed December 11. http://www.energy.ca.gov/sitingcases/ivanpah/.

CEC. 2014c. "Tracking Progress: Once-Through Cooling Phase-Out." August 24. http://www.energy.ca.gov/renewables/tracking_progress/documents/once_through_cooling.pdf.

CEC. 2015. "California Petroleum Statistics and Data." Accessed June 8. http://energyalmanac.ca.gov/petroleum/index.html.

CPUC (California Public Utilities Commission). 2008. *California Energy Efficiency Long-Term Strategic Plan*. San Francisco, CA: California Public Utilities Commission. September. http://www.cpuc.ca.gov/NR/rdonlyres/D4321448-208C-48F9-9F62-1BBB14A8D717/0/EEStrategicPlan.pdf.

CSU (Colorado Springs Utilities). 2014. "Residential Rebate Programs." Accessed December 12. https://www.csu.org/CSUDocuments/2014resrebates.pdf.

Diffenbaugh, N., D. Swain, and D. Touma. 2015. "Anthropogenic warming has increased drought risk in California." Proceedings of the National Academy of Sciences of the United States of America 112(13): 3931–3936. doi: 10.1073/pnas.1422385112.

DOE (U.S. Department of Energy). 2010. *Hardening and Resiliency: U.S. Energy Industry Response to Recent Hurricane Seasons*. Washington, DC: U.S. Department of Energy. August. http://www.oe.netl.doe.gov/docs/HR-Report-final-081710.pdf.

DOE. 2012. *SunShot Vision Study*. Washington, DC: U.S. Department of Energy. February. http://energy.gov/eere/sunshot/sunshot-vision-study.

DOE. 2013. *U.S. Energy Sector Vulnerabilities to Climate Change and Extreme Weather*. Washington, DC: U.S. Department of Energy. http://www.energy.gov/downloads/us-energy-sector-vulnerabilities-climate-change-and-extreme-weather.

DOE. 2014a. *National Electric Transmission Congestion Study*, Draft for Public Comment. Washington, DC: U.S. Department of Energy. August. http://www.energy.gov/sites/prod/files/2014/08/f18/NationalElectricTransmissionCongestionStudy-DraftForPublicComment-August-2014.pdf.

DOE. 2014b. "Energy Incentive Programs." Accessed December 11. http://energy.gov/eere/femp/energy-incentive-programs.

DOE. 2015a. *Quadrennial Energy Review: Energy Transmission, Storage, and Distribution Infrastructure.* Washington, D.C.: U.S. Department of Energy. April. http://energy.gov/sites/prod/files/2015/04/f22/QER-ALL%20FINAL_0.pdf.

DOE. 2015b. "State of California: Energy Sector Risk Profile." Washington, DC: U.S. Department of Energy. http://www.energy.gov/sites/prod/files/2015/05/f22/CA-Energy%20Sector%20Risk%20Profile.pdf.

DOE. 2015c. "State of New Mexico: Energy Sector Risk Profile." Washington, DC: U.S. Department of Energy. http://www.energy.gov/sites/prod/files/2015/05/f22/NM-Energy%20Sector%20Risk%20Profile.pdf.

DOE. 2014d. *Energy Assurance Daily – September 14, 2015.* Washington, DC: U.S. Department of Energy. https://www.oe.netl.doe.gov/docs/eads/ead091415.pdf.

Edwards, J. G. 2009. "Laughlin coal-fired power plant going away." *Las Vegas Review Journal.* June 11. http://www.reviewjournal.com/business/laughlin-coal-fired-power-plant-going-away.

EEI (Edison Electric Institute). 2014. *Before and After the Storm*. Washington, DC: Edison Electric Institute. March. http://www.eei.org/issuesandpolicy/electricreliability/mutualassistance/Documents/BeforeandAftertheStorm.pdf.

EIA (U.S. Energy Information Administration). 2011a. "Distribution and Production of Oil and Gas Wells by State." Accessed December 5, 2014. http://www.eia.gov/pub/oil_gas/petrosystem/petrosysog.html.

EIA. 2011b. "A Quarter of California's electricity comes from outside the state." *Today in Energy.* http://www.eia.gov/todayinenergy/detail.cfm?id=4370.

EIA. 2012. "Electric grid operators monitoring drought conditions." September 4. http://www.eia.gov/todayinenergy/detail.cfm?id=7810.

EIA. 2013a. *Annual Coal Report 2012*. Washington, DC: U.S. Energy Information Administration. December. http://www.eia.gov/coal/annual/.

EIA. 2013b. "Electricity State Level Data: Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923)." Excel data sheet. Washington, DC: U.S. Energy Information Administration. http://www.eia.gov/electricity/data/state/.

EIA. 2013c. *Electric Power Annual 2012*. Washington, DC: U.S. Energy Information Administration. http://www.eia.gov/electricity/annual/.

EIA. 2013d. Existing Nameplate and Net Summer Capacity by Energy Source, Producer Type and State (EIA-860). Washington, DC: U.S. Energy Information Administration. http://www.eia.gov/electricity/data/eia860/.

EIA. 2013f. *Natural Gas Annual 2012*. Washington, DC: U.S. Energy Information Administration. December. http://www.eia.gov/naturalgas/annual/.

EIA. 2013g. *Residential Energy Consumption Survey (RECS) 2009.* Washington, DC: U.S. Energy Information Administration. December. http://www.eia.gov/consumption/residential/.

EIA. 2013h. *Electric power sales, revenue, and energy efficiency (EIA-861).* Washington, DC: U.S. Energy Information Administration. http://www.eia.gov/electricity/data/eia861/.

EIA. 2013i. “Mexico Week: U.S.-Mexico electricity trade is small, with tight regional focus.” May 17. http://www.eia.gov/todayinenergy/detail.cfm?id=11311.

EIA. 2014a. *Petroleum & Other Liquids Data Series: Crude Oil Production*. June 2014. http://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbl_m.htm.

EIA. 2014b. “Natural Gas Consumption by End Use.” Accessed December 5. http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_SDC_a.htm.

EIA. 2014c. “State Energy Profiles.” Accessed October 20. http://www.eia.gov/state/.

EIA. 2014d. *Monthly Biodiesel Production Report*. Washington, DC: U.S. Energy Information Administration. http://www.eia.gov/biofuels/biodiesel/production/.

EIA. 2014e. “Natural Gas: Number of Producing Wells.” Accessed October 20. http://www.eia.gov/dnav/ng/ng_prod_wells_s1_a.htm.

EIA. 2014f. “Natural Gas Pipelines in the Western Region.” Accessed November 17. http://www.eia.gov/pub/oil_gas/natural_gas/analysis_publications/ngpipeline/western.html.

EIA. 2014g. *U.S. Crude Oil Production Forecast - Analysis of Crude Types*. Washington, DC: U.S. Energy Information Administration. May 29. http://www.eia.gov/analysis/petroleum/crudetypes/pdf/crudetypes.pdf.

EIA. 2014h. “Natural Gas Gross Withdrawals and Production.” U.S. Energy Information Administration. Accessed December 5. http://www.eia.gov/dnav/ng/ng_prod_sum_dcu_stx_a.htm.

EIA. 2014i. “Coal Data Browser.” U.S. Energy Information Administration. Accessed December 5. http://www.eia.gov/beta/coal/data/browser/#/topic/20?agg=1,0&geo=vvvvvvvvvvvvo&sec=g&freq=A&start=2008&end=2013&ctype=linechart&ltype=pin&rtype=s&pin=&rse=0&maptype=0.

EIA. 2014k. “Number and Capacity of Petroleum Refineries.” U.S. Energy Information Administration. Accessed February 6, 2015. http://www.eia.gov/dnav/pet/pet_pnp_cap1_dcu_nus_a.htm.

EIA. 2014l. “AEO2014 projects more coal-fired power plant retirements by 2016 than have been scheduled.” U.S. Energy Information Administration. February 14. http://www.eia.gov/todayinenergy/detail.cfm?id=15031.

EIA. 2014m. *Mexico*. Updated April 24, 2014. Accessed March 23, 2015. http://www.eia.gov/countries/analysisbriefs/Mexico/mexico.pdf.

EIA. 2015a. “U.S. Natural Gas Exports and Re-Exports by Point of Exit.” Accessed March 23. http://www.eia.gov/dnav/ng/ng_move_poe2_a_EPG0_ENP_Mmcf_a.htm.

EIA. 2015b. “Renewables and CO_2 emissions.” *EIA Short-term Energy Outlook*. September 9. http://www.eia.gov/forecasts/steo/report/renew_co2.cfm.

EPA (U.S. Environmental Protection Agency). 2014. *Climate Change Indicators in the United States.* Washington, DC: U.S. Environmental Protection Agency. http://www.epa.gov/climatechange/pdfs/climateindicators-full-2014.pdf.

FEMA (U.S. Federal Emergency Management Agency). 2014. “Summary of Databases in Hazus-Multi Hazard.” Accessed October 21. http://www.fema.gov/protecting-our-communities/hazus/summary-databases-hazus-multi-hazard#7.

FERC (Federal Energy Regulatory Commission). 2013. *Assessment of Demand Response and Advanced Metering.* Staff Report. Washington, DC: U.S. Federal Energy Regulatory Commission. http://www.ferc.gov/legal/staff-reports/2013/oct-demand-response.pdf.

Fotland, L. 2012. “SDG&E Implements Fire-Prevention Program.” *Transmission & Distribution World.* May 1. http://tdworld.com/features/sdge-implements-fire-prevention-program.

GAO (Government Accountability Office). 2014. *Climate Change: Energy Infrastructure Risks and Adaptation Efforts*. Washington, DC: GAO. January. http://www.gao.gov/assets/670/660558.pdf.

GAO. 2015. *Technology Assessment: Water in the Energy Sector – Reducing freshwater use in hydraulic fracturing and thermoelectric power plant cooling.* Washington, DC: GAO. August. http://www.gao.gov/assets/680/671913.pdf.

Garfin, G., A. Jardine, R. Merideth, M. Black, and S. LeRoy, eds. 2013. *Assessment of Climate Change in the Southwest United States*. Tucson, AZ: Institute of the Environment. http://swccar.org/sites/all/themes/files/SW-NCA-color-FINALweb.pdf.

Gordon, E. and O. Ojima, eds. 2015. *Colorado Climate Change Vulnerability Study*. Boulder, CO: University of Colorado Boulder and Colorado State University. http://wwa.colorado.edu/publications/reports/co_vulnerability_report_2015_final.pdf.

Grifman, P. M., J. F. Hart, J. Ladwig, A. G. Newton Mann, and M. Schulhof. 2013. *Sea Level Rise Vulnerability Study for the City of Los Angeles*. Los Angeles, CA: University of Southern California Sea Grant Program. http://www.usc.edu/org/seagrant/research/SeaLevelRise_docs/hires_pdfs/City%20of%20LA%20SLR%20Vulnerability%20Study%20FINAL%20Summary%20Report%20Online%20Hyperlinks.pdf.

Hashmi, M., M. Lehtonen, and S. Hänninen. 2013. “Effect of Climate Change on Transformers Loading Conditions in the Future Smart Grid Environment.” *Open Journal of Applied Sciences* 3: 24–29. June. doi:10.4236/ojapps.2013.32B005.

HydroWorld. 2009. “Equipment: Turbine Improvements at Hoover Dam.” *Hydro Review.* http://www.hydroworld.com/articles/hr/print/volume-28/issue-6/featured-articles/cover-story/equipment--turbine.html.

Kasler, D. 2014. “Drought cuts into state’s hydropower supplies.” *The Sacramento Bee*. http://www.energy.ca.gov/commissioners/weisenmiller_docs/articles/2014-02-04_Drought_cuts_into_state_hydro_-_Sacramento_Bee.pdf.

Knowles, N., M. Dettinger, and D. Cayan. 2007. *Trends in snowfall vs. rainfall for the western United States, 1949–2001*. Sacramento, CA: California Energy Commission. April. http://water.usgs.gov/nrp/proj.bib/Publications/2007/knowles_dettinger_etal_2007.pdf.

Landis+Gyr. 2014. "Colorado Springs Utilities Selects Landis+Gyr for Advanced Load Management Program." February 11. http://www.landisgyr.com/colorado-springs-utilities-selects-landisgyr-advanced-load-management-program/.

Litschert, S. E., T. C. Brown, and D. M. Theobald. 2012. "Historic and future extent of wildfires in the Southern Rockies Ecoregion, USA." *Forest Ecology and Management* 269: 124-133, doi:10.1016/j.foreco.2011.12.024.

Macknick, J., S. Sattler, K. Averyt, S. Clemmer, and J. Rogers. 2012. "The water implications of generating electricity: water use across the United States based on different electricity pathways through 2050." *Environmental Research Letters*. 7 045803. December 20. http://iopscience.iop.org/1748-9326/7/4/045803/pdf/1748-9326_7_4_045803.pdf.

Mantell, M. 2011. "Produced Water Reuse and Recycling Challenges and Opportunities Across Major Shale Plays." Presentation at EPA Hydraulic Fracturing Study Technical Workshop #4 Water Resources Management, March 29-30. http://www2.epa.gov/sites/production/files/documents/09_Mantell_-_Reuse_508.pdf.

McCabe, G. J., L. E. Hay, and M. P. Clark. 2007. "Rain on snow events in the western United States." *Bull. Amer. Meteor Soc.* 88: 319–328. March. http://journals.ametsoc.org/doi/abs/10.1175/BAMS-88-3-319.

Miller, N. L., J. Jin, K. Hayhoe, and M. Auffhammer. 2007. *Climate Change, Extreme Heat, and Electricity Demand in California*. Sacramento, CA: California Energy Commission. August. http://www.energy.ca.gov/2007publications/CEC-500-2007-023/CEC-500-2007-023.PDF.

NETL (National Energy Technology Laboratory). 2010. *Water Vulnerabilities for Existing Coal-Fired Power Plants.* August. http://www.ipd.anl.gov/anlpubs/2010/08/67687.pdf.

NOAA (U.S. National Oceanic and Atmospheric Administration). 2013. *Regional Climate Trends and Scenarios for the U.S. National Climate Assessment. Part 5. Climate of the Southwest U.S.* Washington, DC: U.S. National Oceanic and Atmospheric Administration. http://www.nesdis.noaa.gov/technical_reports/NOAA_NESDIS_Tech_Report_142-5-Climate_of_the_Southwest_U.S.pdf.

NRC (National Research Council). 2012. *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future*. Washington, DC: The National Academies Press.

NREL (National Renewable Energy Laboratory). 2014. "Ivanpah Solar Electric Generating System." Accessed December 11. http://www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=62.

Pacific Institute. 2015. *Impacts of California's Ongoing Drought: Hydroelectricity Generation.* March. http://pacinst.org/wp-content/uploads/sites/21/2015/03/California-Drought-and-Energy-Final1.pdf.

Pierce, D. W., T. P. Barnett, H. G. Hidalgo, T. Das, C. Bonfils, B. D. Santer, G. Bala, M. D. Dettinger, D. R. Cayan, A. Mirin, A. W. Wood, and T. Nozawa. 2008. "Attribution of declining western U.S. snowpack to human effects." *Journal of Climate.* Vol. 21 (6425–6444). December. http://caos.iisc.ernet.in/faculty/gbala/pdf_files/Pierce_etal_JCLIM2008.pdf.

PG&E (Pacific Gas & Electric). 2014a. *Corporate Responsibility and Sustainability Report 2014.* Accessed March 19, 2015. http://www.pgecorp.com/corp_responsibility/reports/2014/PGE_CRSR_2014.pdf.

PG&E (Pacific Gas & Electric). 2014b. "PG&E Funds $2 Million in New Fire Detection Cameras." *Currents.* December 23. http://www.pgecurrents.com/2014/12/23/video-pge-funds-2-million-in-new-fire-detection-cameras/.

PG&E (Pacific Gas & Electric). 2015. "New Book on Grid Innovation Includes PG&E Insights, Projects." *Currents.* January 7. http://www.pgecurrents.com/2015/01/07/new-book-on-grid-innovation-includes-pge-insights-projects/.

PNM (Public Service Company of New Mexico). 2011. *Electric Integrated Resource Plan 2011–2030*.

PPIC (Public Policy Institute of California). 2008. *Adaptation of California's Electricity Sector to Climate Change*. San Francisco, CA: Public Policy Institute of California. http://www.ppic.org/content/pubs/report/R_1108EVR.pdf.

Randazzo, R. 2013. "APS closes 3 units at 4 Corners power plant." *The Republic*. December 30. http://www.azcentral.com/business/consumer/articles/20131230aps-closes-units-corners-power-plant.html.

Rolinski, Tom, R. Fovell, S.B. Capps, Y. Cao, B. D'Agostino, and S. Vanderburg. 2014. American Geophysical Union Fall Meeting. San Francisco, CA. December 19. https://agu.confex.com/agu/fm14/meetingapp.cgi#https://agu.confex.com/data/handout/agu/fm14/Paper_17460_handout_1989_0.pdf

Sathaye, J. A., L. L. Dale, P. H. Larsen, G. A. Fitts, K. Koy, S. M. Lewis, and A. F. P. de Lucena. 2012. *Estimating Risk to California Energy Infrastructure from Projected Climate Change*. Sacramento, CA: California Energy Commission. July. http://www.energy.ca.gov/2012publications/CEC-500-2012-057/CEC-500-2012-057.pdf.

SDG&E (San Diego Gas & Electric). 2007. "SDG&E expects 97 percent of fire-impacted customers restored by Nov. 4." Oct. 27. http://www.sdge.com/newsroom/press-releases/2007-10-27/sdge-expects-97-percent-fire-impacted-customers-restored-nov-4.

SDG&E. 2008. Sunrise Powerlink Project Draft Environmental Impact Report/Environmental Impact Statement Attachment 1A: Effect of Wildfires on Transmission Line Reliability. San Diego, CA: San Diego Gas & Electric. January. http://www.cpuc.ca.gov/environment/info/aspen/sunrise/feir/apps/a01/App%201%20ASR%20z_Attm%201A-Fire%20Report.pdf.

SDG&E. 2012. "SDG&E Energizes the Sunrise Powerlink." June 18. http://www.sdge.com/newsroom/press-releases/2012-06-18/sdge-energizes-sunrise-powerlink.

SLC (Salt Lake City). 2014. Sustainable Salt Lake – Plan 2015. Salt Lake City, Utah. December. http://www.slcdocs.com/slcgreen/SustainableSaltLake_2014.pdf.

SWEEP (Southwest Energy Efficiency Project). 2014. *Utility Energy Efficiency Programs in Colorado: A Success Story*. Boulder, CO: Southwest Energy Efficiency Project. http://www.swenergy.org/publications/factsheets/CO_DSM_factsheet_Apr2014.pdf.

Tiedeman, K., S. Yeh, B. Scanlon, J. Teter, and G. S. Mishra. 2014. "Recent Trends in Water Use and Production for California Conventional and Unconventional Oil Production." Accessed on November 11. http://policyinstitute.ucdavis.edu/files/Technical-Brief_Water-Oil_Final.pdf.

Tidwell, Vincent, P. H. Kobos, L. Malczynski, G. Klise, W. E. Hart, and C. Castillo. 2009. "Decision Support for Integrated Water-Energy Planning." http://prod.sandia.gov/techlib/access-control.cgi/2009/096521.pdf.

Troeh, E. 2012. "An oil refinery secures an essential material: water" *Marketplace.* August 21. http://www.marketplace.org/topics/sustainability/oil-refinery-secures-essential-material-water.

USACE (U.S. Army Corps of Engineers). 2014. "Waterborne Commerce of the United States: Calendar Year 2012 Part 4 – Waterways and Harbors Pacific Coast, Alaska and Hawaii". Alexandria, VA: U.S. Army Corps of Engineers. http://www.navigationdatacenter.us/wcsc/pdf/wcuspac12.pdf.

UCS (Union of Concerned Scientists). 2012. UCS EW3 Energy-Water Database V.1.3. Cambridge, MA: Union of Concerned Scientists. www.ucsusa.org/ew3database.

USBR (U.S. Bureau of Reclamation). 2000. *Permissible Loading of Oil-Immersed Transformers and Regulators*. Denver, CO: U.S. Bureau of Reclamation, Facilities Engineering Branch. September. http://www.usbr.gov/power/data/fist/fist1_5/vol1-5.pdf.

USBR. 2009. "Glen Canyon Dam Photo Gallery." Denver, CO: U.S. Bureau of Reclamation. July 29. http://www.usbr.gov/uc/rm/crsp/gallery/gc-gallery/pages/pg3.html.

U.S. Census Bureau. 2014. "State & County QuickFacts." Accessed July 22. http://quickfacts.census.gov/qfd/index.html.

U.S. Department of Commerce. 2013. "NIST Releases Study on Reducing Damage and Loss from Wildfires." Washington, DC: U.S. Department of Commerce. September 4. http://2010-2014.commerce.gov/blog/category/2417.

USGCRP (U.S. Global Climate Research Program). 2014. *Climate Change Impacts in the United States: The Third National Climate Assessment.* Washington, DC: U.S. Global Change Research Program. http://nca2014.globalchange.gov/report.

USGS (U.S. Geological Survey). 2005. "Estimated Use of Water in the United States: County-Level Data for 2005." http://water.usgs.gov/watuse/data/2005/index.html.

USGS. 2015. "Las Vegas, Nevada, USA." *Earthshots: Satellite Images of Environmental Change.* U.S. Department of the Interior U.S. Geological Survey. April 2. http://earthshots.usgs.gov/earthshots/Las-Vegas#ad-image-4.

USNRC (U.S. Nuclear Regulatory Commission). 2015. "Palo Verde Nuclear Generating Station, Unit 1." Washington, DC: U.S. Nuclear Regulatory Commission. February 5. http://www.nrc.gov/info-finder/reactor/palo1.html.

Vicuna, S., R. Leonardson, M. Hanemann, L. Dale, and J. Dracup. 2007. "Climate change impacts on high elevation hydropower generation in California's Sierra Nevada: a case study in the Upper American River." *Climatic Change 87* (Suppl 1):S123–S137. November 23. http://meteora.ucsd.edu/cap/pdffiles/Vicuna_hydropower_jan2008.pdf.

White House. 2015. "Announcing the First Class of Climate Action Champions." Washington, DC: the White House. December 3. https://www.whitehouse.gov/blog/2014/12/03/announcing-first-class-climate-action-champions.

WWA (Western Water Assessment for the State of Colorado). 2011. *Colorado Climate Preparedness Project*. Boulder, CO: University of Colorado, Boulder. http://wwa.colorado.edu/publications/reports/WWA_ColoClimatePreparednessProject_Report_2011.pdf.

Xcel Energy. 2015. "Colorado Clean Air-Clean Jobs Plan." Accessed March 20. http://www.xcelenergy.com/Environment/Doing_Our_Part/Clean_Air_Projects/Colorado_Clean_Air-Clean_Jobs_Plan.

Chapter 3 Endnotes

[a] Source: NOAA 2013
[b] Sources: DOE 2013, NOAA 2013, USGCRP 2014
[c] Sources: NOAA 2013, USGCRP 2014
[d] Sources: DOE 2013, Tiedeman et al. 2014, USGCRP 2014
[e] Sources: Cayan et al. 2013, NOAA 2013, USGCRP 2014
[f] Sources: AEG and Cubed 2005, Garfin et al. 2013, Vicuna et al. 2007, USGCRP 2014
[g] Source: USGCRP 2014
[h] Sources: Sathaye et al. 2012, USGCRP 2014
[i] Sources: NOAA 2013, USGCRP 2014
[j] Changes in CDDs are regional (see Figure 2), compared to 1980–2000 (NOAA 2013). Increases in *per capita* average peak demand by end of the century compared to 2003–2009 under A2 scenario (Sathaye et al. 2012).
[k] Sources: NOAA 2013, NRC 2012, USGCRP 2014
[l] Capacity reductions represent effects of increased ambient temperature on California's natural gas-fired generators and include projections of incremental increased temperature in 2070–2099 (Sathaye et al. 2012). Coal plants identified by NETL 2010. There are 25 plants located in 100-year floodplain assuming 1.4 meter relative SLR (Climate Central 2014a).
[m] Sources: Cayan et al. 2013, NOAA 2013, USGCRP 2014
[n] 1971–2000 compared to 2070–2099 (USGCRP 2014)
[o] Sources: NOAA 2013, Sathaye et al. 2012, USGCRP 2014
[p] Increases in transmission line and substation capacity losses are for California, by the end of the century, depending on region, and compared to current levels (Sathaye et al. 2012).